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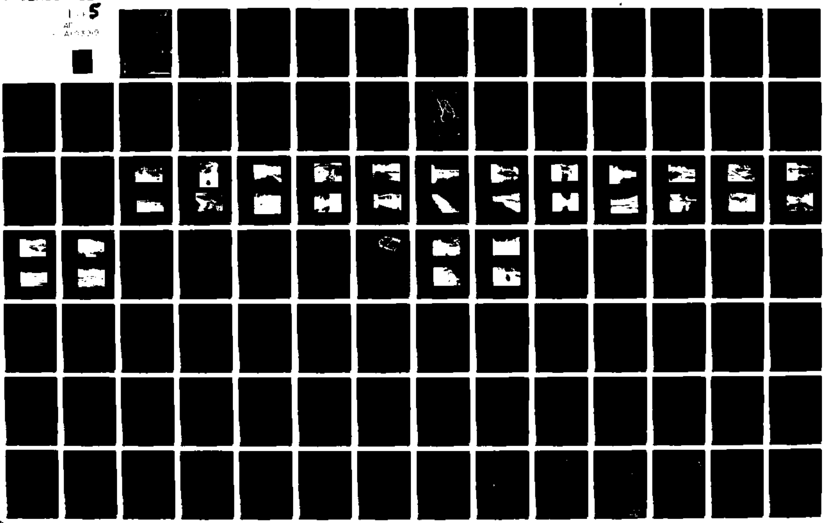

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CUYAHOGA RIVER, OHIO RESTORATION STUDY

THIRD INTERIM PRELIMINARY FEASIBILITY REPORT ON EROSION AND SEDIMENTATION

VOLUME II - APPENDICES A THROUGH H

U.S. ARMY CORPS OF ENGINEERS, BUFFALO DISTRICT
1776 NIAGARA STREET
BUFFALO, NEW YORK 14207

November 1979
(Revised April 1981)

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APPENDIX A

IDENTIFICATION OF SOURCES OF EROSION

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this appendix is to identify the sources of sediment in the Cuyahoga River Basin between Independence, Ohio (river mile 13.8) and old Portage, Ohio (river mile 40.25). The sediment entering the river system is derived from erosion of the streambanks and the upland area. The highly erodible principal soil types are composed of silts and sands. Geologic, climatic, and hydrologic factors affect the rate at which soil erosion occurs. For example, soils with steep slopes that are unprotected by vegetative cover erode faster

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than those on flatter slopes. Erosion is also greater for areas with high annual precipitation and long, cold winters, where vegetation is either dormant or destroyed. The Cuyahoga RiverBasin historically has had serious erosion and sedimentation as displayed by onsite physical evidence, complaints, and various attempts of remedial actions by local interests. The problem is demonstrated by the naming of the Cuyahoga demonstrated by the naming of the Cuyahoga River which is derived from Indian words meaning "Crooked River", and the original settler naming of the tributary streams in the area such as Mud Brook, Sand Run, and Yellow Creek.

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
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IDENTIFICATION OF SOURCES OF EROSION

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THIRD INTERIM PRELIMINARY FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

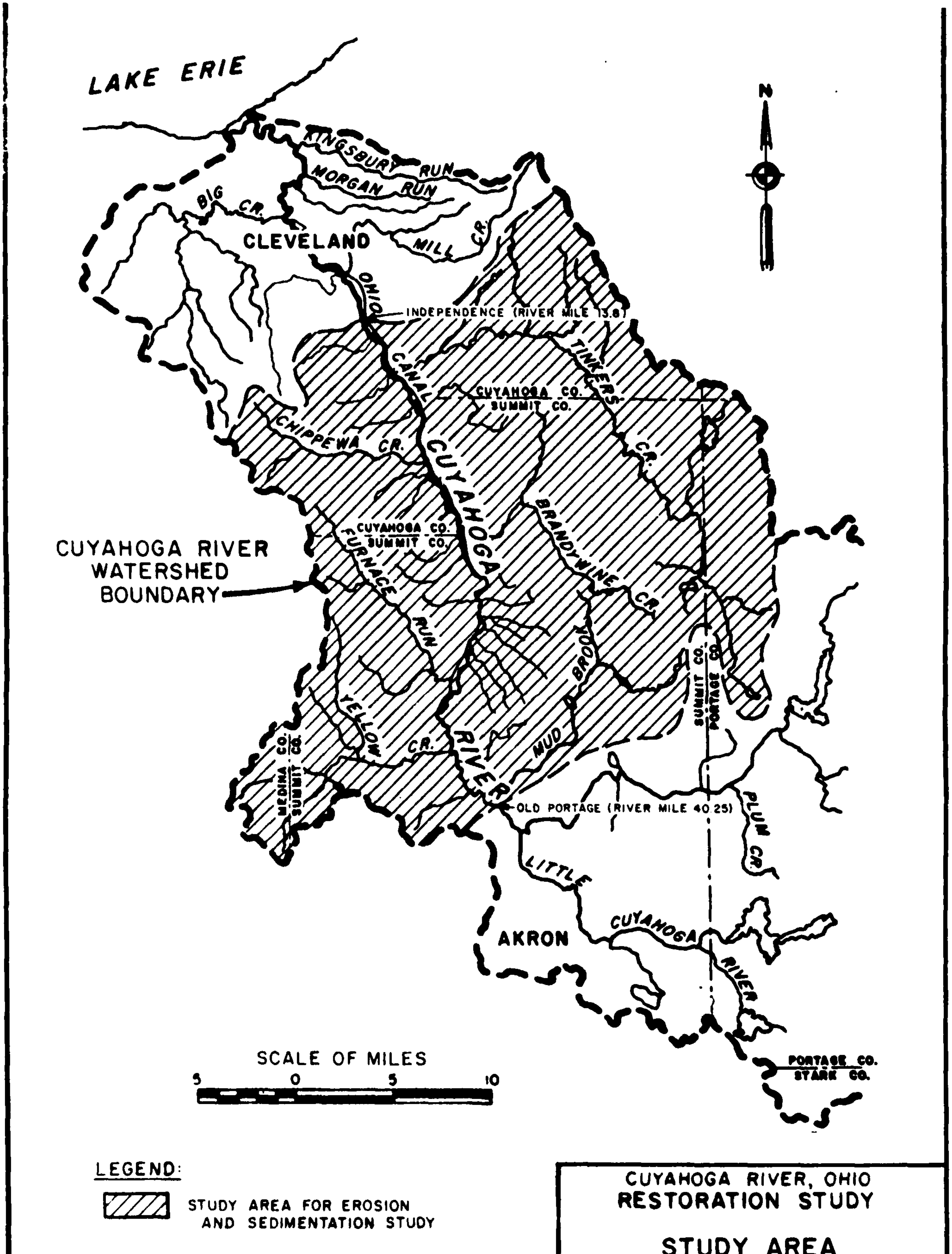
APPENDIX A

IDENTIFICATION OF SOURCES OF EROSION

A1. INTRODUCTION

The purpose of this appendix is to identify and quantify the sources of sediment in the Cuyahoga River Basin between Independence, OH (river mile 13.8) and Old Portage, OH (river mile 40.25). The sediment entering the river system is derived from erosion of the streambanks and the upland area. The highly erodible principal soil types are composed of silts and sands. Geologic, climatic, and hydrologic factors affect the rate at which soil erosion occurs. For example, soils with steep slopes that are unprotected by vegetative cover erode faster than those on flatter slopes. Erosion is also greater for areas with high annual precipitation and long, cold winters, where vegetation is either dormant or destroyed. The Cuyahoga River Basin historically has had serious erosion and sedimentation as displayed by onsite physical evidence, complaints, and various attempts of remedial actions by local interests. The problem is demonstrated by the naming of the Cuyahoga River which is derived from Indian words meaning "Crooked River," and the original settler naming of the tributary streams in the area such as Mud Brook, Sand Run, and Yellow Creek.

Previous studies in the recent past have indicated the major erosion and sedimentation problem areas are in the lower Cuyahoga River Basin between Independence (river mile 13.8) and Old Portage (river mile 40.25) (see Figure A1.1). Dr. Robert Apmann, for example, in his report on "Erosion and Sedimentation of the Cuyahoga River Basin," (1973) identified the lower Cuyahoga River Basin as the most prolific source of sediment in the river system. These findings were confirmed by a United States Geological Survey (USGS) 1-year suspended sediment gaging program in the lower Cuyahoga River Basin. This program consisted of establishing nine suspended sediment gaging stations at the locations shown on Figure A1.2. Data was collected for the period of December 1976 to November 1977. The data indicated that approximately 20,000 tons of suspended sediment passed through the gage at Old Portage (404 square-mile drainage area) and approximately 235,000 tons passed through the gage at Independence (an additional 303 square-mile drainage area or 707 square-miles total). This means that 215,000 tons of suspended sediment was added to the river system in this 303 square-mile drainage area. This amount of suspended sediment justifies concentrating the study effort in this river basin reach. The USGS data also indicated that there are significant erosion and sedimentation contributions from the tributary watersheds. It indicated that Tinkers Creek and Brandywine Creek are contributing the heaviest suspended sediment loads (29,000 tons per year and 10,000 tons per year, respectively), and Furnace Run has the highest sediment yield (550 tons per square-mile per year). Copies of Dr. Apmann's report and the USGS report on their "Suspended Sediment Sampling Program" are included in Appendix E as



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

STUDY AREA
ORIENTATION MAP

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A1.1

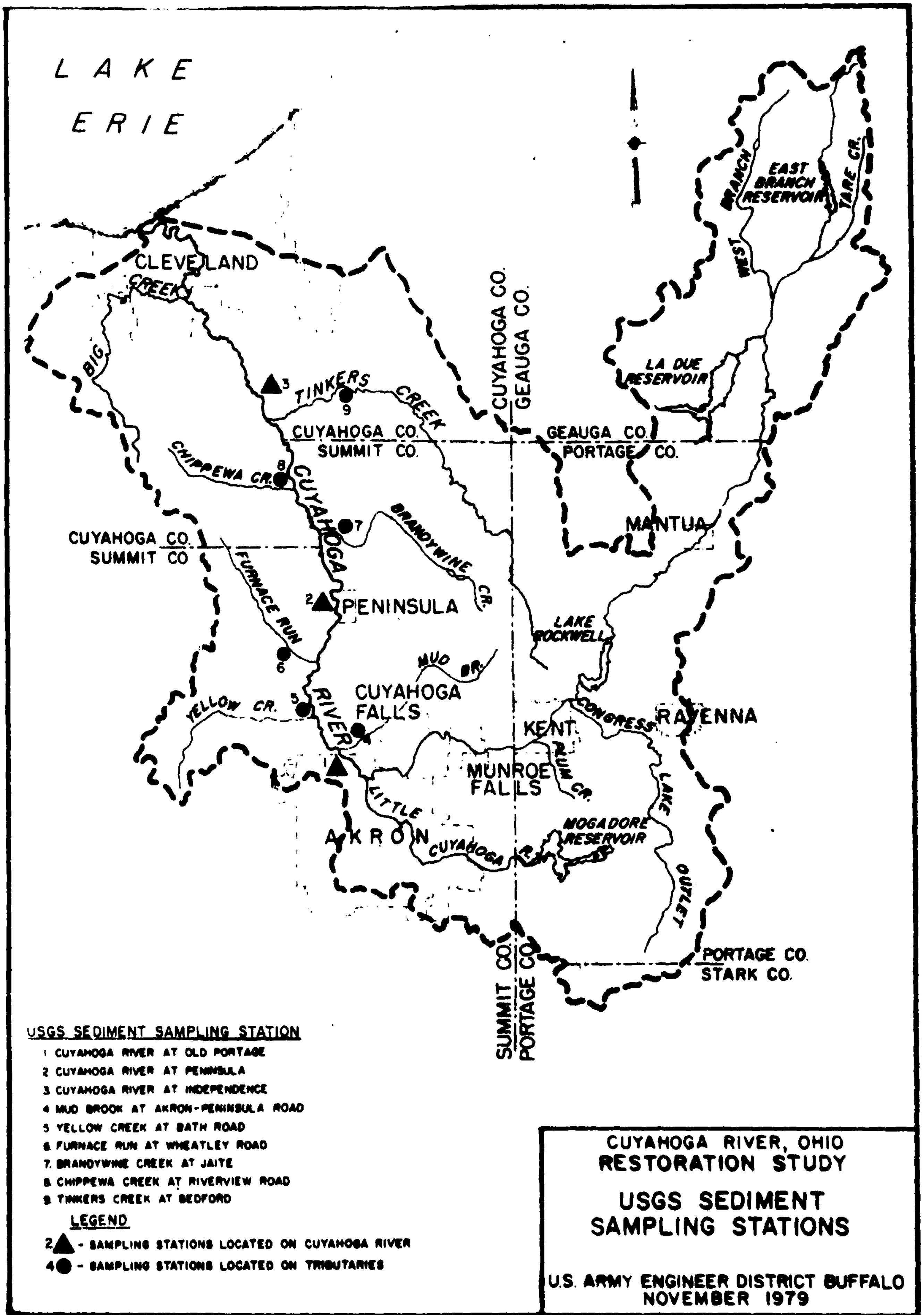

LAKE
ERIE
CLEVELAND
BIG CREEK
TINKERS CREEK
CHIPPEWA CR.
CUYAHOGA RIVER
BRANDYWINE CR.
FURNACE RUN
YELLOW CR.
MUD BR.
LITTLE CUYAHOGA R.
PENINSULA
CUYAHOGA FALLS
AKRON
KENT
MUNROE FALLS
RAVENNA
MANTUA
LAKE ROCKWELL
CONGRESS
PLUM CR.
LAKE OUTLET
MOGADORE RESERVOIR
LA DUE RESERVOIR
EAST BRANCH RESERVOIR
WEST BRANCH
TARE CR.
CUYAHOGA CO.
GEAUGA CO.
SUMMIT CO.
PORTAGE CO.
STARK CO.
USGS SEDIMENT SAMPLING STATION
1 CUYAHOGA RIVER AT OLD PORTAGE
2 CUYAHOGA RIVER AT PENINSULA
3 CUYAHOGA RIVER AT INDEPENDENCE
4 MUD BROOK AT AKRON-PENINSULA ROAD
5 YELLOW CREEK AT BATH ROAD
6 FURNACE RUN AT WHEATLEY ROAD
7 BRANDYWINE CREEK AT JAITE
8 CHIPPEWA CREEK AT RIVERVIEW ROAD
9 TINKERS CREEK AT BEDFORD
LEGEND
2▲ - SAMPLING STATIONS LOCATED ON CUYAHOGA RIVER
4● - SAMPLING STATIONS LOCATED ON TRIBUTARIES
CUYAHOGA RIVER, OHIO
RESTORATION STUDY
USGS SEDIMENT
SAMPLING STATIONS
U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A1.2

Exhibits E-1 and E-2, respectively. Table A1.1 is a summary of the USGS data which was used to select tributaries needing additional channel studies as discussed in Section A2 of this appendix.

The study was divided into two components or individual study areas; the channel component and the upland watershed component. The channel component consists of the main stem (main channel) of the Cuyahoga River and the channels of the six major tributaries which enter the river within the study area. The channel component will identify and estimate the quantity of sediment derived from erosion of the channel banks. The upland watershed component consists of the 303 square-mile watershed area between Independence and Old Portage. The upland watershed component will identify sediment sources and estimate the sediment delivered to the Cuyahoga River from erosion of the land surface.

The following sections of this appendix will present the results of the studies conducted for each component. Each section will start with a general introduction, followed by a detailed description of the component study area, a review of the methodologies used to identify and quantify the sources of sediment, and the results of the studies conducted.

A2. CHANNEL COMPONENT

a. GENERAL - The channel component consists of the main stem of the Cuyahoga River from Independence (river mile 13.8) to Old Portage (river mile 40.25) and the channels of the six major tributaries in this reach (see Figure A2.1). The tributaries are Mud Brook, Brandywine Creek, and Tinkers Creek on the east side of the basin, and Yellow Creek, Furnace Run, and Chippewa Creek on the west side of the basin. A sediment gage was established by the USGS on each of these tributaries at varying distances from the Cuyahoga River in order to estimate the annual suspended sediment yield of each tributary. These sediment gages are in addition to the sediment gages established on the main stream of the Cuyahoga River.

Two tributaries, Brandywine Creek and Tinkers Creek, were selected to be studied over their entire length. The USGS gage data (a copy of the USGS report is included in Appendix E) indicated that these two tributaries were the most significant sediment producers of the six tributaries studied. Tinkers Creek had a suspended sediment loading of approximately 29,000 tons per year and Brandywine Creek had a suspended sediment loading of approximately 10,000 tons per year. Also, Table A1.1 is a summary chart which utilized the USGS data to rank the tributaries in order of sediment volume, sediment rate, suspended sediment particle size, and tributary location to the downstream study limits. Visual observations of the six tributaries during high runoff periods by SCS personnel confirmed the USGS data.

While Brandywine Creek and Tinkers Creek were studied over their entire length, the remaining four tributaries were only studied from their confluence with the river to the location of the USGS sediment gaging station. A substantial amount of bank erosion was observed to be taking place in these reaches. The data collected for Brandywine and Tinkers Creeks cannot be expanded to include the remaining four tributaries due to the physical

Table A1.1 - Summary of Data from USGS Report on Cuyahoga River Suspended Sediment Gaging Program

(Sample Period 12/76 - 11/77)

Tributary	Sed. Volume		Sediment Rate		Size of Suspended Sed.*		Location of Tributary**
	Tons	Rank	Tons/mi 2/	Rank		Rank	
Tinkers Creek	28,657	1	342	3	Slightly Coarser	3	1
Brandywine Creek	10,414	2	383	2	Almost Identical	1	3
Furnace Run	9,665	3	546	1	Coarser	4	4
Yellow Creek	9,169	4	299	5	Much Coarser	6	5
Mud Brook	7,820	5	267	6	Coarser	5	6
Chippewa Creek	5,984	6	338	4	Slightly Coarser	2	2

*Particle size of sediment in tributary stream as compared to the particle size of sediment in Cuyahoga River at Independence Gage.

**Rating based on nearness of tributary outlet to downstream limit of study area.

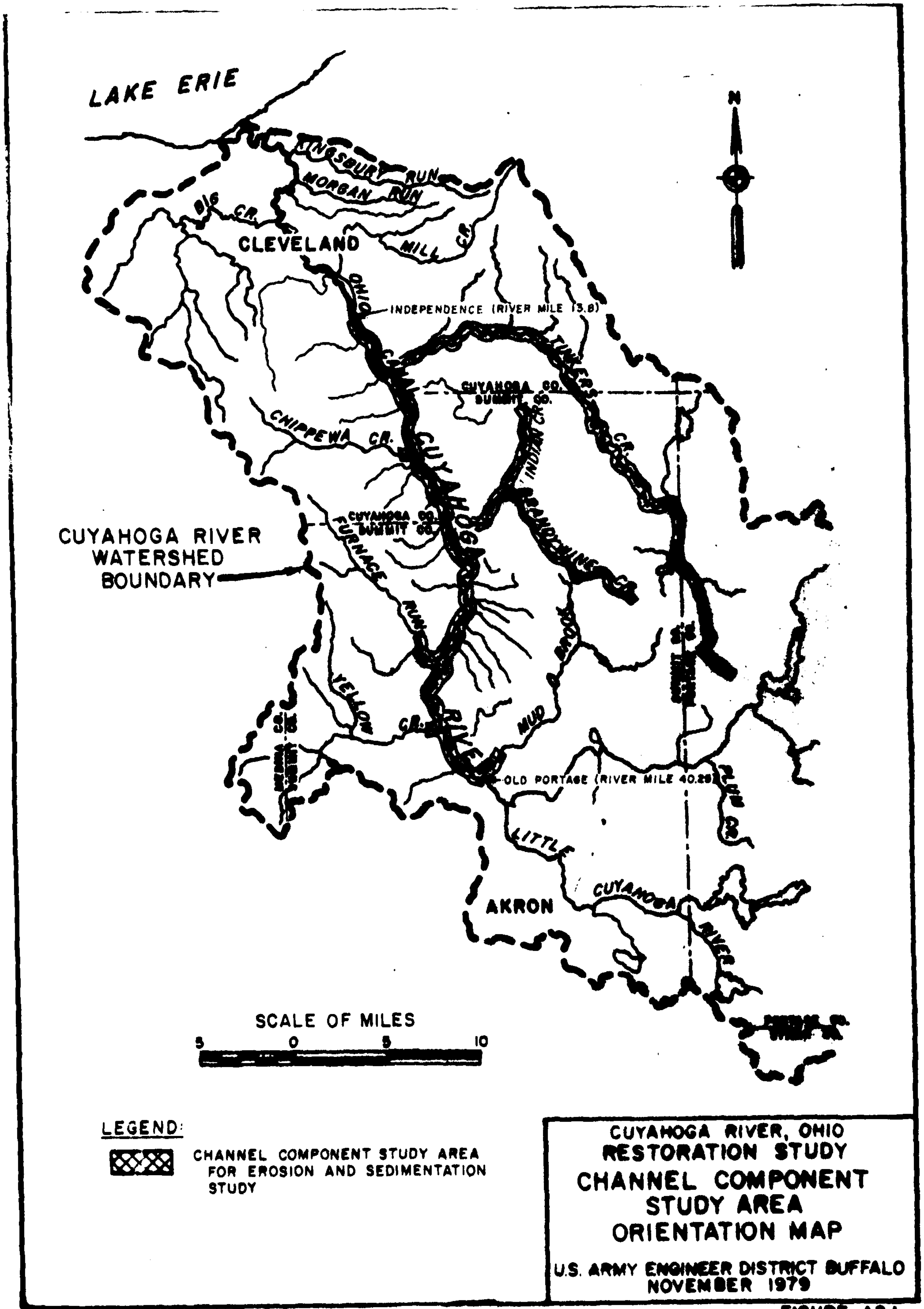

LAKE ERIE
KINGSBURY RUN
MORGAN RUN
BIG CR.
CLEVELAND
MILL CR.
OHIO CANAL
INDEPENDENCE (RIVER MILE 13.8)
TINKERS CR.
CUYAHOGA CO.
SUMMIT CO.
CHIPPEWA CR.
INDIAN CR.
CUYAHOGA
BRANDYWINE CR.
FURNACE RUN
CUYAHOGA RIVER
WATERSHED
BOUNDARY
YELLOW CR.
MUD BROOK
RIVER
OLD PORTAGE (RIVER MILE 40.29)
FISH CR.
LITTLE CUYAHOGA RIVER
AKRON
SCALE OF MILES
5 0 5 10
LEGEND:
CHANNEL COMPONENT STUDY AREA FOR EROSION AND SEDIMENTATION STUDY
CUYAHOGA RIVER, OHIO
RESTORATION STUDY
CHANNEL COMPONENT
STUDY AREA
ORIENTATION MAP
U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A2.1

differences of the channels and the varying degrees of urban and industrial development. Additional channel inventories will be completed for the Final Feasibility Report (FFR) on Furnace Run and Mud Brook if the recommendation of this report is to continue into Stage 3 planning, because extensive areas of bank erosion were observed while collecting the field data for the upland component study area. Mud Brook will be studied from the USGS gage (stream mile 0.2) to stream mile 8.0, and Furnace Run will be studied from the USGS gage (stream mile 1.5) to stream mile 7.0. In addition, the first two miles of Wheatly Run, a tributary of Furnace Run, will also be studied. The remaining two tributaries (Chippewa Creek and Yellow Creek) will not be inventoried due to field observations that indicated channel erosion was not a significant problem in these tributaries.

b. DESCRIPTION OF STUDY AREA - The following paragraphs present a brief narrative of the conditions observed while collecting and recording the channel component field data required to calculate sediment production from bank erosion. Right/left notations refers to the banks while facing downstream. Plates A2-1 to A2-5 in Appendix I are large scale reference maps of the channel component study area.

(1) Main Stem of the Cuyahoga River.

Portage Path Bridge to Bath Road

(River Mile 40.25 to River Mile 37.4)

This reach of the river extends approximately 3.1 miles. Two tributaries enter the river in this reach as well as the discharge from the Akron Wastewater Treatment Plant. Mud Brook enters from the east at river mile 39.8 and Sand Run from the west at river mile 39.3. Each of these tributaries have deposited sediment and debris bars near their confluence with the Cuyahoga River. This sediment consists of coarse-grained material. The sediment and debris bars are not causing an erosion problem at this time. In the past, however, the sediment bar below Sand Run caused a relocation of the Cuyahoga River. This is substantiated by comparing the changing course of the river recorded on aerial photos from 1937, 1951, 1969, and 1977.

Approximately 3,000 feet of channel bank should be armored in this reach of the river because of high rates of bank erosion. A high percentage of the erosion is on the channel banks where the land use is forest. This is due to the woody debris buildup in the river. This debris (log jams) diverts the river flow into the banks at several locations. The concentration of diverted river flow erodes the bank toe causing it to slip. In addition, apartment housing is being developed on the flood plain at river mile 40.2 on the left bank (Photo A2.1). The bank is exposed and eroding from construction disturbance. At river mile 39.7 on the right bank, a crop field is eroding. This streambank is located on the outside of a curve and the banks are bare. This channel bank is 25 feet high and is eroding at the rate of 1 foot per year (Photo A2.2).

The river in the area of the Akron Wastewater Treatment Plant (river mile 38) is stable. This is due to the straight alignment and the well-established vegetation (large trees) in this reach (Photo A2.3). Sludge bars have formed

in the river downstream of the Akron Wastewater Treatment Plant. These bars are causing no erosion problems, but are unsightly.

Bath Road to Ira Road

(River Mile 37.4 to River Mile 35.6)

The river in this reach is stable primarily due to the forest vegetation covering the streambank. Yellow Creek enters the Cuyahoga River from the west at river mile 37.3, just downstream of Bath Road. There are four areas in this reach of the river that need to be armored. These are located on the outside of curves. Two of the areas are in cropland. The original woody vegetation has been removed for cropland purposes, and the banks are currently bare (Photo A2.4). Another area is adjacent to woodland, and the bank erosion is primarily caused by poor channel alignment. The fourth unstable reach occurs on both banks of the river at river mile 36 and is adjacent to Riverview Road. Old tires and stone have been dumped on the left bank to protect the road. This practice has slowed the rate of bank erosion. This 400-foot section needs to be armored.

Ira Road to Bolanz Road

(River Mile 35.6 to River Mile 33.7)

No major tributaries enter the Cuyahoga in this reach. At approximate river mile 34.7, the river makes a sharp bend, and erosion is taking place. The right bank at this location borders on a crop field and is eroding at the rate of approximately 1.5 feet per year (Photo A2.5). The river also overflows its banks during high flow periods at this location, causing flood plain scour (Photo A2.6). The river will change course here in the future, causing the loss of cropland and the addition of large quantities of sediment to the river system. Another problem at this location is connected with a major power line. Construction of the power line has eliminated most of the bank vegetation, thereby encouraging erosion. Debris and sediment bars are not causing a problem in this reach.

Bolanz Road to State Route 303

(River Mile 33.7 to River Mile 29.6)

The Cuyahoga River stretches approximately 4.1 miles from Bolanz Road to State Route 303 in Peninsula. Furnace Run enters the Cuyahoga River from the west at river mile 33.5.

The river meanders in a 3-mile reach immediately downstream of Furnace Run. There are several reasons for this. First, the channel grade increases in this stretch causing an increase in velocities and a tendency to scour. Second, the bank material is made up of silts and sands which tend to be easily erodible and unstable. Third, the land uses along the river are primarily cropland and pasture land. This results in little permanent vegetation cover to prevent erosion. Continuous row cropping has been practiced on these bottom land fields for many years (Photo A2.7).

The existing woody debris in the river below Furnace Run is not causing erosion problems. There are also several sediment and bedload bars in this reach. Field observations and aerial photos trace the bedload material to Furnace Run. The formation of sediment bars forces the flow of the river against the opposite bank with increasing velocities, thereby causing increased bank erosion. Some sediment bars should be removed, however, it is probable that they would return unless the river alignment is changed, or the source of the material is controlled in the Furnace Run Watershed.

The last mile of this reach, just upstream of Peninsula, is stable and is contributing no sediment to the river. In this area, the channel has armored itself, and the banks are heavily vegetated (Photo A2.8).

State Route 303 to Ohio Turnpike

(River Mile 29.6 to River Mile 27.6)

The Cuyahoga River is fairly stable from Peninsula to the Ohio Turnpike. Although the river has a steep gradient in this reach, it also has a rock-lined bottom and heavily vegetated banks which prevent bank erosion (Photo A2.9).

Slipper Run, a tributary entering just downstream of Peninsula, is forming a large bedload bar in the Cuyahoga River. This bar is not causing any particular erosion problem to the banks.

There is a 300-foot reach where bank erosion is occurring in an old river meander at approximate river mile 28.9. This 300-foot reach erodes only during times of high flow.

At river mile 28.2, the right bank is eroding for a distance of 1,400 feet. The bank material is silty which contributes to the bank's instability. This area also has the only recorded marsh adjacent to the streambank. This wetland area is also a factor in the streambank instability due to water seepage through the silts (Photo A2.10).

Ohio Turnpike to Cuyahoga County Line

(River Mile 27.6 to River Mile 25.8)

There is only one major problem area on the river from the Ohio Turnpike to the Cuyahoga County Line. At river mile 26.2, there is a bend in the river which is eroding. This bend is at a point where the river, the railroad, and Riverview Road all coincide. The bank material here is sandy. This area needs to be armored to prevent future streambank erosion (Photo A2.11).

The remaining portions of this reach are stable. A sediment bar has formed at the mouth of a small tributary that handles the runoff from the Boston Mills Ski Resort. This bar is not causing an erosion problem to the streambank.

Cuyahoga County Line to Brecksville Dam

(River Mile 25.8 to River Mile 21.4)

From the Cuyahoga County line to Brecksville Dam, severe bank erosion exists. The river has recently changed courses at several locations. Each time the river changes course, a large amount of sediment is introduced into the river system.

The river has formed a new channel at Jaite, near the mouth of Brandywine Creek (river mile 24.8). The river has eroded its bank during high flow periods establishing a shorter course across the meander neck (Photo A2.12). Another place where a change of course has occurred is at river mile 23.1. Here again, the river has eroded its bank and shortened its course. Both of these areas need to be armored to prevent further erosion of the streambanks.

The topsoil along the left side of the river has been stripped from river mile 25.8 to river mile 25.2, and this has lowered the streambanks in the area. This allows the river to leave its banks during periods of high flow and scour the flood plain. This same situation exists downstream from river mile 24.3 to 24.1 on the right bank. The banks in both areas need to be reconstructed to prevent this overland flow. These areas contribute large amounts of sediment to the river system during periods of high flows.

Two methods of streambank protection have been attempted in this reach. Gabions have been used in a 400-foot reach at river mile 25.7 on the left bank. They are approximately 4 feet high and have successfully protected a reach of the streambank where a pipeline crosses the river. From river mile 25.1 to river mile 24.9, the left bank has been protected with the use of old automobile bodies. These automobiles have been placed side by side and nose down for a distance of 1,200 feet. They are anchored to the bank by cables. Although rather unsightly, the cars have protected the bank reasonably well (Photo A2.13). The left bank immediately downstream of this car body protected area is eroding and needs to be armored.

There is a large crop field along the right bank from river mile 22.9 to river mile 22.1. This bank is eroding and needs to be armored (Photo A2.14).

The banks are stable for a one-half mile reach just upstream of the Brecksville Dam. This is due to the backwater effect of the Brecksville Dam which reduces flow velocities and well-established woody vegetation (Photo A2.15). Chippewa Creek enters the Cuyahoga River from the west at river mile 21.7 in this backwater reach.

Brecksville Dam to Fitzwater Road

(River Mile 21.4 to River Mile 18.2)

This reach of the river has heavy woody vegetation which prevents streambank erosion (Photo A2.16). There is a bedload bar in this reach that needs to

be removed at river mile 19.6 since it diverts the stream flow into the left bank, causing bank erosion.

There is a problem area at river mile 19 where there is a large oxbow. The oxbow is about 3,000 feet long and needs to be armored for the entire length (Photo A2.17).

Fitzwater Road to Hillside Road

(River Mile 18.2 to River Mile 16.4)

There is one major problem in this reach at river mile 17.8 on the right bank. The Ohio Canal is very near the river, and if the streambank erosion continues unchecked, the canal will be damaged. This reach should be armored.

There is also erosion occurring at river mile 17.9 in the vicinity of Pleasant Valley Road where the river has formed an island. This erosion can be controlled with woody and grassy vegetation.

Tinkers Creek, one of the larger tributaries of the Cuyahoga River, enters the river from the east at river mile 17.2. Most of the heavy bedload material from Tinkers Creek is deposited upstream of the Ohio Canal Aqueduct. The finer-grained material, however, is delivered directly to the Cuyahoga River.

Hillside Road to Old Rockside Road

(River Mile 16.4 to River Mile 13.8)

This reach of the Cuyahoga River has several erosion problems. The worst problem is the stripping of topsoil from the flood plain at river mile 16.2 (Photo A2.18). Sediment is added to the river system during major storm events by flood plain scour because the soil mining operation has left the ground uncovered and has reduced the streambank height. The streambank needs to be reconstructed and armored to keep the river within its defined channel. The same situation occurs at river mile 15.5 on the left bank. Again, the bank needs to be reconstructed.

A bar has developed at river mile 15 downstream of Stone Road. The bar is composed of bedload material (gravel). Bank erosion is taking place because the bar deflects the river flow against the bank, but this can be controlled by vegetative means (Photo A2.19). The river has changed course at river mile 14.6 within the past 3 years. This is documented on recent aerial photographs. Approximately 1,000 feet of channel has been eliminated and a large quantity of sediment has been added to the river system. This area needs to be armored to prevent further meandering.

Picket fences constructed from pipe and wooden planks are being used to control streambank erosion at river mile 14.3. Although the picket fences are controlling streambank erosion, they are not aesthetically pleasing, and they could be a hazard to canoeists using the river (Photo A2.20)

(2) Tributaries Studied to the USGS Sediment Gage.

Mud Brook (to sediment gage) - There is 1,000 feet of Mud Brook between the sediment gage and the Cuyahoga River. The land adjacent to this reach is urbanized and the channel banks are moderately eroding. This erosion can be controlled by establishing grassy vegetation.

Yellow Creek (to sediment gage) - The sediment gage on Yellow Creek was located 4,200 feet upstream from the Cuyahoga River. The bridges for Riverview Road and the railroad constrict the flow of Yellow Creek and trap substantial amounts of sediment. This trapped sediment then causes the creek to meander (Photo A2.21).

Approximately 1,300 feet of Yellow Creek needs to be armored, and 700 feet needs to have bar removal. Several homeowners are losing up to 1 foot per year from their backyard areas. This erosion is the result of high stream velocities. There is also a massive landslide located on the left bank of Yellow Creek, which is contributing large amounts of sediment (Photo A2.22).

Furnace Run (to sediment gage) - The sediment gage was located approximately 8,000 feet upstream of the Cuyahoga River. Furnace Run is much like Yellow Creek in that sediment is being trapped behind or upstream of the railroad bridge. The channel meanders above the bridge with scouring taking place on the outside of curves and deposition on the inside. Most of the material being deposited is coarse-grained. The fine-grained material is entering the Cuyahoga River system. Approximately 1,400 feet of banks on Furnace Run need to be armored in this reach and 3,200 feet need to have bar removal.

Chippewa Creek (to sediment gage) - The sediment gage was located on the Riverview Road bridge 1,900 feet upstream from its mouth. The mouth of Chippewa Creek has been moved upstream on the Cuyahoga River approximately 200 feet to give additional space for an industrial development. This area has now been purchased by the National Park Service as part of the Cuyahoga Valley National Recreation Area. This outlet change is unsightly, but is not contributing as much sediment as its appearance indicates because the banks are composed of weathered shale (Photo A2.23). No protective or corrective measures are recommended for the outlet area of Chippewa Creek at this time. Chippewa Creek is stable to the stream gage except for a few isolated eroding areas due to lack of vegetation. These areas can be protected by grassy and woody revegetation.

(3) Tributaries Studied for Their Entire Length.

Brandywine Creek - Brandywine Creek is approximately 12 miles in length. It reaches from Jaite in the Cuyahoga Valley to Hines Hill Road just north of Hudson.

The stream is divided into three major reaches - the flood plain reach (stream mile 0 to stream mile 1.5), the transition reach (stream mile 1.5 to stream mile 3.8), and the plateau reach (stream mile 3.8 to stream mile 11.6). The reaches have different characteristics and problems.

The flood plain reach has nearly all of the erosion problems of the three reaches. A change in the course of the Cuyahoga River (at river mile 25.8) moved the Brandywine Creek outlet downstream 1,600 feet. The creek meanders several times in an 1,800-foot reach upstream of the sediment gage (stream mile 0.3 to stream mile 0.6). The creek banks are unstable because of high flow velocities and recent channel realignment within the Brandywine Ski Resort. The erosion can be controlled by shaping and seeding the banks.

The remainder of the flood plain reach (stream mile 0.6 to stream mile 1.5) flows along the base of the Brandywine Ski Resort. Channel bank erosion is taking place in this reach. There is little or no bank vegetation in this area due to the Ski Resort activities. In addition, stream velocities are increased due to the steep channel gradient just upstream of the Ski Resort. A combination of armoring and seeding is needed to protect this reach.

The transition reach is basically stable. There is, however, one section of bank erosion within this transition reach located in a landslide area at stream mile 1.8. Armoring of the streambanks is needed. The channel is rock-lined from stream mile 1.8 to stream mile 3.9, preventing erosion even though the grade is very steep.

The plateau reach begins at stream mile 3.9 where Brandywine crosses under Interstate 271. The channel grade flattens, and there is no significant bank erosion. The vegetation is well-established on both banks. There are some sediment bars due to the low velocities, but these are causing no problems. The creek is stable from stream mile 3.9 to stream mile 8.2 where it flows under the Ohio Turnpike. The 400-foot reach of the creek just above the Turnpike is eroding and should be armored.

Brandywine Creek next flows through Lake Forest Country Club. The Club has installed gabions which are controlling erosion on the side slopes and bottom of the creek for a distance of 700 feet. The gabions are the outlet for the 40-acre Lake Forest on Brandywine Creek. The area above the lake is eroding due to home construction adjacent to the creek. The bank at this location needs to be armored to prevent further erosion.

Another lake (Pine Lake) has been built on Brandywine from stream mile 9.3 to stream mile 9.8. This lake is in a residential area. Above Pine Lake, stream mile 9.8 to stream mile 11.6, the size of the creek is greatly reduced and no erosion occurs.

Indian Creek, the largest tributary of Brandywine Creek, was also studied. It enters Brandywine from the north at stream mile 4.0. There is only one reach of Indian Creek that is eroding. Home construction has disturbed the channel for a distance of 1,500 feet, north of Macedonia (stream mile 2.3). The banks, as well as the entire construction area, need to be stabilized with grass vegetation (Photo A2.24).

Tinkers Creek - Tinkers Creek was inventoried from its mouth at the Cuyahoga River (river mile 17.2, stream mile 0.0), to Route 303, stream mile 27.3. It can be divided into four major reaches - the flood plain reach (stream mile 0.0 to stream mile 2.3), the transition reach (stream mile 2.3

to stream mile 6.3), the plateau reach (stream mile 6.3 to stream mile 23.0), and the marsh reach (stream mile 23.0 to stream mile 27.3). As in Brandywine Creek, the reaches are well-defined, and only one reach contains the majority of the erosion problems.

The Canal Road bridge and the Ohio Canal Aqueduct cross Tinkers Creek at stream mile 0.1. Both are severely restricting stream flow in the creek. The channel is unstable in several places upstream of the bridges (Photo A2.25). This reach is very susceptible to meandering and sediment bar formation. There is little substantial vegetation in the flood plain reach. A major power line right-of-way extends part way up the valley. This right-of-way disturbance has encouraged bank erosion (Photo A2.26). At stream mile 1.5 on the left bank, there is a massive landslide (Photo A2.27). The material in this bank is saturated and unstable. The bank at this location needs to be armored to prevent further erosion. Just downstream of Dunham Road, the left bank is eroding. The channel gradient is very steep just upstream of this location. The high velocities entering this reach are causing the erosion. Large quantities of coarse material have been deposited in this area (Photo A2.28). This material could be utilized by taking it from the channel bottom and placing it against the left bank, otherwise this reach should be armored. Dunham Road is the upstream limit of the flood plain reach.

The transition reach, Dunham Road to the stream gage in Bedford, contains little erosion. The stream is rock-lined for the entire reach. This area of Tinkers Creek flows through the Bedford Reservation of the Cleveland Metro Parks. The channel banks are well vegetated and stable.

The plateau reach extends from the stream gage in Bedford to stream mile 23 at the junction of Tinkers Creek and Pond Brook. The erosion problems in this reach are entirely man-made. Wherever man has altered the course of the stream, erosion is taking place. The most dramatic example of man's interference is just upstream of Pettibone Road. Here the channel has been moved to the west approximately 500 feet to make additional room for a sanitary landfill. The streambank is severely gullied on the landfill side of the creek. This reach needs to be stabilized with grass vegetation and armoring. At stream mile 14.2, the creek is eroding due to the encroachment of a housing development. The sections of the channel which remain undeveloped are stable in this reach due to the flat stream grade and the abundance of bank vegetation.

The upper reach of Tinkers Creek is marshland. Erosion is not a problem in this area.

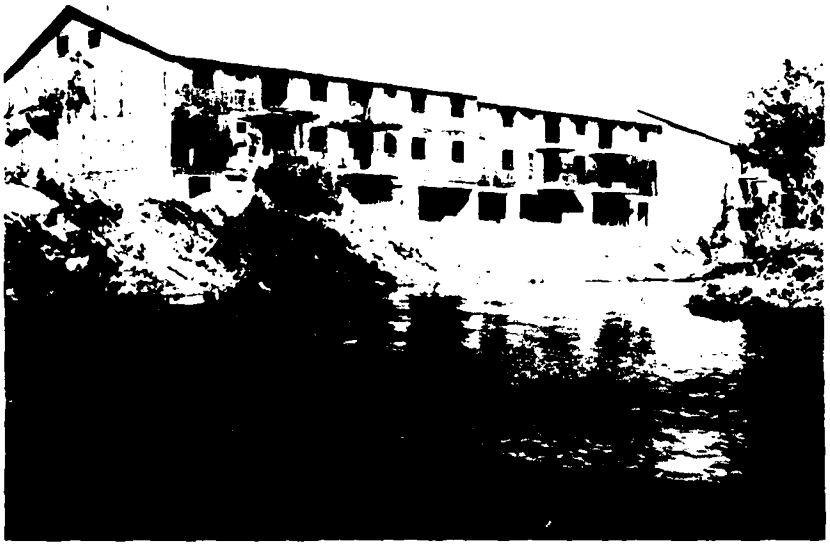


Photo A2.1 - River mile 40.2, flood plain development and bank encroachment (SCS 10/77.)

Photo A2.2 - River mile 39.7, river bend with 25-foot high eroding bank (SCS 10/77.)

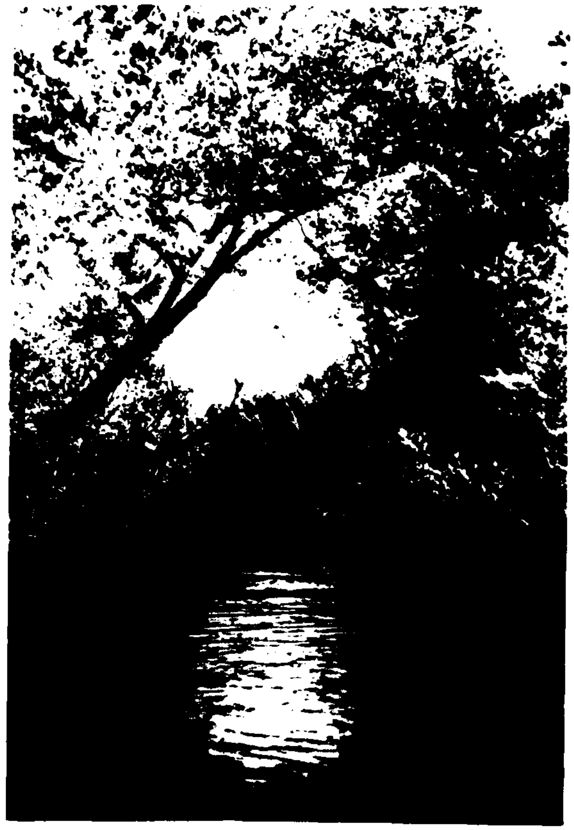


Photo A2.3 - River mile 38.0, scenic Cuyahoga River with overhanging tree canopy.

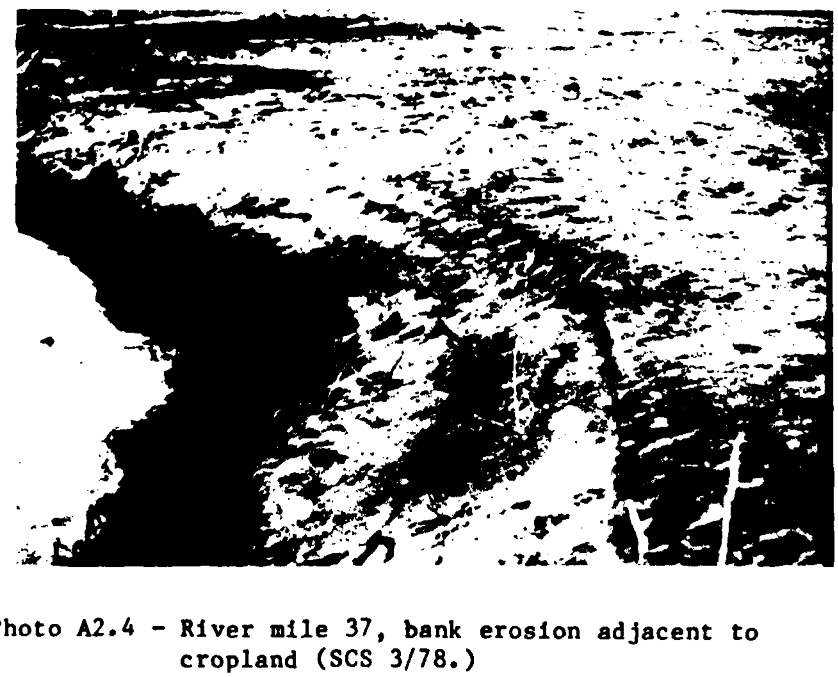


Photo A2.4 - River mile 37, bank erosion adjacent to cropland (SCS 3/78.)

Photo A2.5 - River mile 34.7, bank erosion adjacent to cropland (SCS 3/78.)

Photo A2.6 - River mile 34.7, flood plain scour (SCS 3/78.)

Photo A2.7 - River mile 30.5, bank erosion adjacent to cornfield (SCS 3/79.)

Photo A2.8 - River mile 30, stable banks due to heavy vegetation (SCS 7/78.)

Photo A2.9 - River mile 29, stable banks due to heavy vegetation and rock lined river bottom (SCS 6/78.)

Photo A2.10 - River mile 28.2, wetlands area adjacent to the Cuyahoga River (SCS 7/78.)

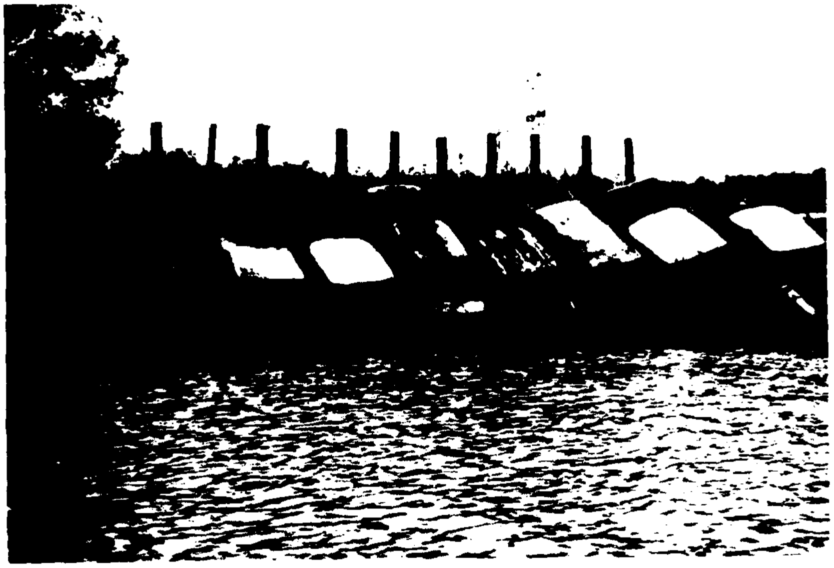


Photo A2.13 - River mile 25.0, car bodies used to stabilize eroding streambank (SCS 6/78.)

Photo A2.14 - River mile 22.2, bank erosion adjacent to cropland. Note cracks in soil where next portion will fall into river.

Photo A2.11 - River mile 26.2, eroding streambank
(SCS 6/78.)

Photo A2.12 - River mile 24.8, eroding streambank
(SCS 4/78.)

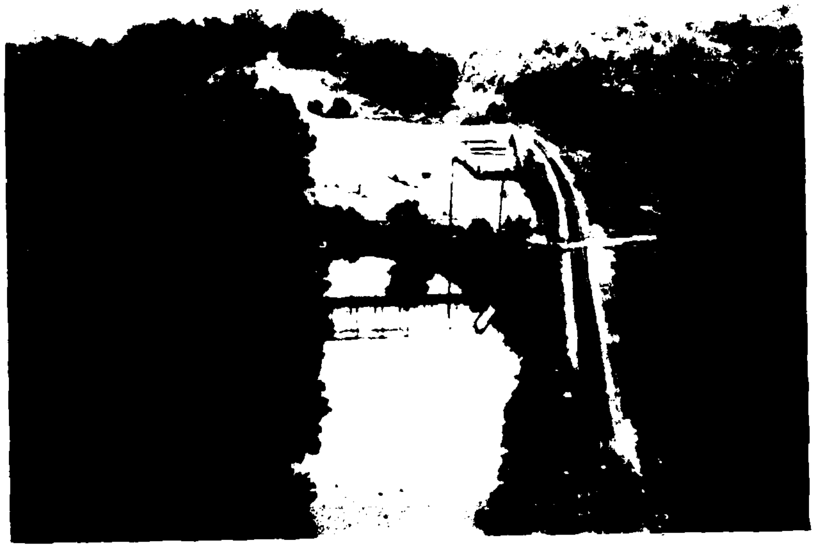


Photo A2.15 - River mile 21.5, stable streambank. Note well-established vegetation (SCS 7/78.)

Photo A2.16 - River mile 20.5, stable streambanks. Note heavy woody vegetation (SCS 6/78.)

Photo A2.17 - River mile 19, eroding streambank at oxbow in the river (SCS 7/78.)

Photo A2.18 - River mile 16.2, topsoil mining operation. Note absence of vegetative covering (SCS 7/78.)

Photo A2.19 - River mile 15, gravel bar which deflects the river flow against the streambank causing erosion (SCS 9/77.)

Photo A2.20 - River mile 14.3, picket fences controlling streambank erosion (SCS 7/78.)

Photo A2.21 - Stream mile 0.2 (Yellow Creek), sediment deposition area (SCS 4/78.)

Photo A2.22 - Stream mile 0.6 (Yellow Creek), landslide adjacent to Yellow Creek (SCS 3/79.)

Photo A2.23 - Stream mile 0.0 (Chippewa Creek), relocated outlet of Chippewa Creek (SCS 9/77.)

Photo A2.24 - Stream mile 2.1 (Indian Creek), erosion due to urban development (SCS 6/79.)

Photo A2.25 - Stream mile 0.1 (Tinkers Creek), streambank erosion. Note formation of sediment bars (SCS 5/78.)

Photo A2.26 - Stream mile 0.2 (Tinkers Creek), streambank erosion caused by construction of power-line (SCS 5/78.)

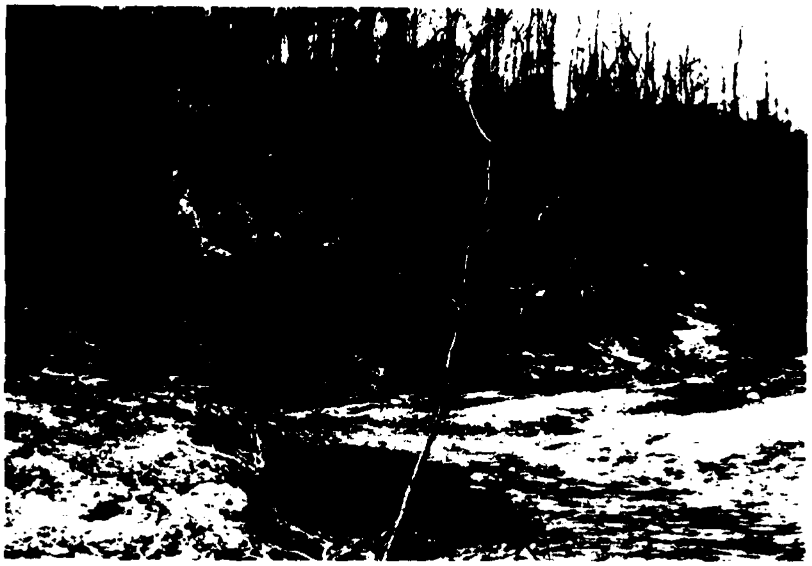


Photo A2.27 - Stream mile 1.5 (Tinkers Creek), landslide adjacent to Tinkers Creek (SCS 5/78.)

Photo A2.28 - Stream mile 2.3 (Tinkers Creek), deposition area in Tinkers Creek (SCS 5/78.)

c. METHODOLOGIES AND APPROACHES USED TO IDENTIFY EROSION PROBLEM AREAS - Sediment produced from streambank erosion was classified as either annual streambank erosion or meander changes. Annual streambank erosion is the average amount of soil loss from the banks of a stream in 1 year. Meander changes are areas where the stream changes its course during a major runoff event. The methods used to estimate streambank erosion and the type of data that was collected for each category is discussed below.

(1) Annual Streambank Erosion - A streambank data survey was conducted by the Soil Conservation Service from September 1977 to September 1978 to estimate annual lateral recession (the primary variable used in quantifying the amount of annual streambank erosion in the channel component study area). A small boat was used to collect the streambank data. It was found that the most advantageous position to observe the streambanks was from the center of the river. The river was divided into short reaches of similar characteristics, and data was recorded for each reach. The entire river was observed and inventoried once. Various random locations were monitored during the following year to verify the correctness of the initial observations. These random spot checks substantiated the initial observations. The following information was typically recorded for each reach:

Streambank Section Number - The stream was divided into individual reaches of similar characteristics. The reach section changed when conditions changed along the streambank. Typically, the length of the reach ranged from 200 to 1,000 feet.

Type of Stream - The streambanks were designated as being either natural or modified. The stream was classified as natural where it has not been altered by man. If straightening or bank shaping had taken place, the stream was classified as modified.

Stream Width - The width of the stream was estimated from waterline to waterline at normal flow.

Adjacent Land Use - The land use adjacent to the stream was noted. The land use categories were pasture, cropland, forest, urban, and other areas. Other areas included small farmsteads, cut and fill areas, and roads.

Fencing Along Bank - If the streambank was fenced, it was so noted.

Mapping Symbol of Adjoining Soil Type - The soil type along the channel was obtained from soil surveys made by the Soil Conservation Service and the Ohio Department of Natural Resources, Division of Lands and Soil. The major soil types along the Cuyahoga River and its tributaries are Chagrin silt loam, Holly silt loam, and Tioga loam. These soils are within the flood plain and are formed in recent alluvium. They are made up of sands and silts. Erosion and flooding are severe hazards on these soils.

Present Erosion Treatment - Banks that had been treated for erosion control were recorded.

Bank Erosion - Where a bank was eroding, the length, height, and average annual lateral recession of the bank was recorded for each reach. The average annual lateral recession of the reach was estimated in a three-step process as follows:

(a) The first step was to develop Plates A2-6 and A2-7 in Appendix I (Changes in River Channel) prior to actual field work. These plates depict the approximate location of the river channel in the years 1938, 1963, 1967, and 1977 based on aerial photos for 1938 (SCS) and 1977 (Ohio Department of Transportation) and the USGS topographic maps published in 1963 and 1967. These plates indicated where major areas of bank erosion occurred in the past and alerted field personnel to potential areas of high erosion rates. It was not feasible, however, to calculate bank recession rates from these plates because the scales of the aerial photos and topographic maps were too large for accurate measurement (i.e., 1 inch equals 2,000 feet for the topographic maps).

(b) The second step involved evaluating the existing physical evidence within each reach during the streambank survey (age of the vegetation, exposure of any plant roots, cracks in the streambank, active bank sloughing, etc.). This evaluation indicated whether or not bank erosion in the reach was significant (average annual lateral recession greater than 1 foot per year). For example, at river mile 20 (Photo A2.29), existing vegetation was dense and well-established. The condition of the streambank was stable as indicated by the absence of cracks in the banks or bare exposed areas. Therefore, it was concluded that this reach did not contain significant bank erosion. Conversely, at river mile 22.2 (Photo A2.30), the streambank lacked permanent vegetation, had visible cracks, and active bank sloughing. Therefore, this reach was classified as a significant area of bank erosion.

(c) Once it was determined whether or not bank erosion was significant for the reach under study, the final step was to estimate the average rate of annual lateral recession. For reaches where bank erosion was not significant (less than 1 foot per year), the annual rate of recession was estimated from the change in character of exposed roots to protective stem tissue, such as bark, on perennial or woody plants. When a plant root is exposed to the air, the outside cell structure changes to protective tissue which causes the exposed root to increase in diameter on an annual basis. By examining the exposed roots and noting the various levels of diameter changes, recession rates can be estimated based on the distance between these changes. The same principle is used to determine the age of a tree by counting its annual growth rings.

For reaches where bank erosion was significant, recession rates were estimated by: (1) locating stable banks in adjacent reaches; (2) drawing a line between these stable points following the general configuration of the stream; (3) measuring the distance between this established line and the eroding bank; and (4) assuming this measured recession occurred in 1 year. These annual rates were then adjusted based on discussions with local individuals familiar with the area.

(d) As previously discussed, the average rate of annual lateral recession for each eroding streambank was estimated by SCS personnel once during the time frame of September 1977 to September 1978. Various random locations were also monitored during the following year to verify the correctness of the initial observations. In addition, a separate verification study was conducted by personnel of the Buffalo District during the fall of 1980. This verification study consisted of an analysis of aerial photos of the Cuyahoga River for the years 1938 and 1979. By comparing the position of the river banks at randomly selected locations for these 2 years, an estimate of the historical rate of annual lateral recession was obtained. These historical annual lateral recession rates were then compared to the SCS estimate at the same location. Based on this analysis, it was determined that the SCS estimate of annual lateral recession was accurate to the degree necessary for making an assessment of the problem and no further verification studies were required. Additional details of this verification study are provided in Inclosure 1 at the end of this Appendix.

Treatment Needed - A method of streambank protection was recommended for all eroding streambanks while collecting field data for the streambank survey. These suggested treatments were based on observations made by Soil Conservation Service personnel during the inventory. These observations guided the formation of alternatives presented in Appendix C. The following is a short description of these methods and the criteria used to select one method over another is presented in Appendix C.

Simple - This involves establishing vegetation along the streambank (Photo A2.29).

Trash and Bar Removal - This involves removal of trash and sediment deposits where it diverts the flow of the stream against the streambank increasing bank erosion (Photo A2.31).

Armoring - This involves armoring the banks with stone (Photo A2.32).

The above data was collected for the entire channel component study area, and the volume of annual streambank erosion was calculated. A typical completed data sheet is shown in Figure A2.2.

(2) Meander Changes - Meander changes are defined for this report as areas where the river has formed a new channel during a high flow event. This change in the channel is caused by erosion of the alluvium flood plain soils and typically occurs at large bends in the river (meander loops). When the river is confined to a narrow flood plain due to geologic features, meander changes do not occur. It is important to remember that meander changes are not areas that are gradually eroding. They are areas where a high flow event has cut a new channel and may occur during any major storm event.

As shown on Plates A2-6 and A2-7, meander changes occur frequently on the Cuyahoga River and are a significant source of sediment. Therefore, a study was conducted to predict where major meander changes would occur in the future. The first step in this study was to locate meander changes that had taken place to gain a understanding of the physical characteristics of the area where they occurred and the sediment load they introduced into the river system. This was accomplished by interpreting Plates A2-6 and A2-7 to locate areas where the river had changed course supplemented with field checks to confirm the findings. Quantities of sediment was then estimated by calculating the volume of material displaced during formation of the new channel (average cross-sectional area multiplied by the length of the new channel).

The second step was to use this knowledge to predict where new meander changes could occur. Areas with similar characteristics were identified in the field while conducting the streambank survey. The sites that were identified were then visited during or immediately after high flow periods to look for evidence that the river was attempting to change course. Evidence sought out was overland flow in a confined area, as indicated by flood plain scour or debris deposition in the flood plain, and excessive erosion on the outside banks of a meander loop. This excessive bank erosion causes the width of the meander loop neck to narrow, and if allowed to continue

Date ______

Technician ______

State ______

Co ______

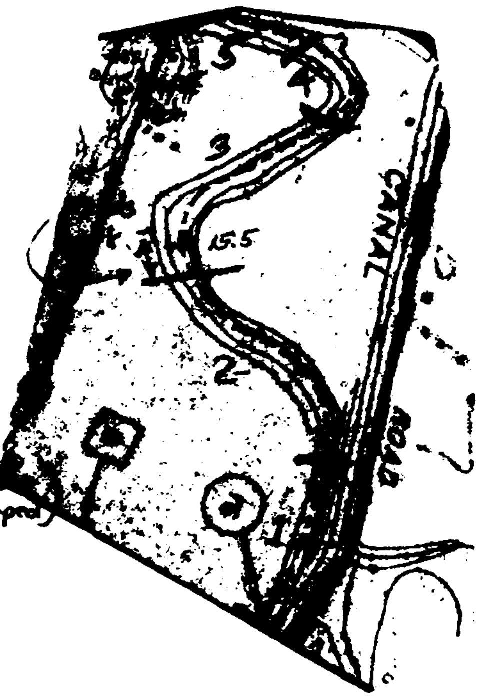
SAMPLE AND RECORD

Streambank Erosion Study

Sample Sheet #23

Stream Ident. 22	Stream-bank (L,R) and Sect. No. 23-25	Type of stream (S,M,N) 26	Length of section (feet) 27-30	Stream width (feet) 31-34	Adj. Land Use 35	Is bank fenced? 36	Field mapping symbol of adjoining soil series 37-41	Present erosion trend 42	Is bank eroding? 43	Complete if Eroding: Avg. bank height 44-47	Annual lateral recess 48-51	Trees needed 52
[illegible]	L 1	N	1000	[illegible]	[illegible]	[illegible]	Ch	—	NO	10.0	—	M
	2	N	1400	90	F	NO	Ch	—	NO	10.0	—	M
	3	M	1200	90	O	NO	CF	—	NO	9.0	—	M
	4	N	600	90	F	NO	CF	—	NO	7.0	—	M
	5	N	500	90	F	NO	CF	—	NO	7.0	—	M
16.0	R 1	N	1000	70	F	NO	Ch	—	NO	12.0	—	M
	2	N	1400	80	O	NO	Ch	—	YES	8.0	0.7	S
	3	N	1200	80	F	NO	Ch	—	NO	8.0	—	M
	4	N	600	90	O	NO	Ch	—	YES	8.0	0.7	S
	5	M	500	90	U	NO	Ch	—	NO	11.0	—	M

Remarks - Drawings



Rubble (dumped)

FIGURE A2.2-TYPICAL STREAMBANK SURVEY DATA SHEET

Photo A2.29 - River mile 20.0, stable streambanks. Note dense well-established vegetation (SCS 7/78.)

Photo A2.30 - River mile 22.2, streambank erosion. Note visible crack in bank and absence of vegetation (SCS 4/78.)

Photo A2.31 - River mile 39.4, trash and bar buildup. Note eroding bank (SCS 10/77.)

Photo A2.32 - Armored streambank (Chippewa Creek-tributary to Mushgingham River, courtesy SCS.)

unchecked, could reduce the width sufficiently to allow the river to breach and establish a new channel. Quantities of sediment were then estimated based on the existing cross-sectional area of the stream at the potential meander site and assuming the shortest overland route.

d. CHANNEL COMPONENT EROSION PROBLEM AREAS - This section presents the results of the studies conducted to identify and quantify the sources of sediment from streambank erosion. As previously mentioned, streambank erosion was classified as either annual streambank erosion or meander changes. The results of the studies for these two types of streambank erosion are discussed below.

(1) Annual Streambank Erosion - Annual streambank erosion is the average amount of soil loss from the banks of a stream in 1 year. Although this type of streambank erosion is expressed as an annual figure, it primarily occurs during high flow periods. It is definitely not a continuous action occurring twelve months of the year.

The following discussion is grouped into five subsections: (a) main stem of the Cuyahoga River (river mile 13.8 to river mile 40.25); (b) tributaries studied to the USGS sediment gage (Chippewa Creek, Furnace Run, Yellow Creek, and Mud Brook); (c) Brandywine Creek (stream mile 0.0 to stream mile 11.6); (d) Tinkers Creek (stream mile 0.0 to stream mile 27.3); and (e) summary and general conclusions. Each subsection will discuss the annual streambank erosion occurring in the reach under study and will correlate bank erosion with adjacent land use and soil type. This correlation will be used in Appendix C as a guide for selection of various treatment measures to control streambank erosion. This correlation can also be used by other interests as a guide to predicting where bank erosion could occur in noninventoried areas of the Cuyahoga River Basin (i.e., upstream of river mile 40.25, etc.).

(a) Main stem of the Cuyahoga River - There are 53 miles of streambanks in the study area along the main stem of the Cuyahoga River. This includes both banks so that in one river mile there are two miles of streambanks. As shown on Table A2.1, of the 53 miles of streambanks studied only 14.4 miles, or 27 percent, are actively eroding. The location of these eroding streambanks are shown on Plates A2-8 and A2-9 in Appendix I. Each area of streambank erosion is identified by two sets of numbers. The first set of numbers refers to the river mile where the eroding streambank is located. The second set refers to the particular reach within that river mile. For example, 21-6 refers to river mile 21 and reach 6. Areas with extensive reaches of streambank erosion are located between river mile 14.5 to 16.4; river mile 17.8 to 19.3; river mile 22.1 to 26.5; river mile 30.4 to 31.8; and river mile 32.0 to 33.3. The remaining areas of streambank erosion are scattered throughout the remaining reaches of the river.

Table A2.2 presents the calculations that were made to estimate the volume of sediment introduced into the Cuyahoga River from annual streambank erosion. Each eroding reach of the river identified during the streambank data survey previously discussed is listed, along with its corresponding length, average rate of annual lateral recession, and bank height. The volume of sediment was then calculated for each reach by multiplying the length, the average

rate of annual lateral recession and the bank height and dividing by the conversion factor of 27 cubic feet per cubic yard. As indicated, 24,000 cubic yards (or 36,000 tons) of sediment are annually added to the river from annual streambank erosion. In addition, Table A2.2 indicates that areas that contribute significant volumes of sediment are concentrated in five sections of the river: (1) river mile 13.8 to 15.1; (2) 18.0 to 20.0; (3) 22.0 to 25.0; (4) 26.0 to 27.0; and (5) 30.0 to 33.0. These reaches contribute 19,000 cubic yards per year (28,500 tons), or 79 percent of the total volume, while accounting for only 65 percent of the total length of eroding streambanks. Table A2.2 also indicates that the rate of annual lateral recession ranged from a high of 5.0 feet per year at reach 26-3 to zero for several areas. The majority of the eroding reaches had rates of annual lateral recession between 0.1 and 1.5 feet per year.

Trash (dead trees, construction debris, etc.) and bedload bar buildup is a contributing factor to the high rates of annual lateral recession at several locations. Trash buildup gouges the bank as it becomes lodged and deflects the river flow either into the toe of the bank, causing undercutting, or into the river bed, causing scouring. Although there are numerous locations where this occurs, an attempt was made to locate only those areas that would not be cleared during bank-shaping operations while constructing bank protection measures. These trash buildup locations are shown on Table A2.3 with the corresponding eroding reach of the river which it affects.

Bedload bar buildup reduces the channel cross-section, causing an increase in flow velocity and a resultant increase in the erosion force of the river. Since the alluvium soils of the streambanks offer less resistance to erosion than the bedload bars, this increased erosion force acts against the streambanks resulting in higher rates of annual lateral recession. The locations where this occurs are also shown on Table A2.3.

There are also several locations, as shown on Table A2.4, where topsoil stripping operations along the main stem have lowered the existing streambank. This allows the river to leave its banks during periods of above-average flow, causing flood plain scour. Although the quantity of sediment eroded from the flood plain during periods of overbank flow was not quantified for this report, it is believed to be significant in these areas since these areas have no permanent protective vegetative cover and are thus susceptible to erosion. No evidence of deposition in these areas was observed immediately following periods of overbank flow.

There are also four sites along the main stem where damage to local roads and railroad facilities will occur in the future because of the high rates of annual lateral recession at these locations. Site No. 1 occurs at river mile 24.6 where Highland Road crosses the Cuyahoga River. Based on the estimated annual lateral recession rate for eroding reach 24-3 (3 feet per year) damage to the road can be expected within 20 years. Site No. 2 occurs at river mile 35.0 where Akron-Peninsula Road is located in close proximity to the river. Based on the estimated annual lateral recession rate for eroding reach 35-1 (2 feet per year) damage to the road can be expected within 15 years. Site No. 3 occurs at river mile 14.8 where the Baltimore and Ohio Railroad (Chessie System) tracks are located in close proximity to the river. Based

on the estimated annual lateral recession rate for eroding reach 14-3 (1.5 feet per year) damage to the railroad tracks can be expected within 10 years. Site No. 4 occurs at river mile 26.2 where the B&O tracks are again in close proximity to the river. Based on the estimated annual lateral recession rate for eroding reach 26-4 (1.5 feet per year) damage to the railroad tracks can be expected within 10 years. Damage to these railroad tracks will adversely impact on the industries located in Cleveland since these tracks are one of the major trunk lines serving the city of Cleveland.

Table A2.5 presents a comparison of total miles of streambanks versus miles of eroding streambanks by adjacent land use. As shown on this table, 72 percent of the streambanks are forested, but they account for only 51 percent of the eroding streambanks. It appears that the forest cover absorbs part of the kinetic energy of the river before it comes in contact with the soil surface and thus greatly reduces the erosion potential of the river. The forested banks that are eroding occur primarily on the outside of sharp bends in the river where the erosion forces of the river are greater. Table A2.5 also shows that, although cropland and other land (cut and fill areas, roads, and small farmsteads) comprise only 16 percent of the total length of streambanks studied, they account for 40 percent of the eroding streambanks. It appears that this is caused by man disturbing the protective vegetative covering which leaves the soil bare and exposed to the full erosive force of the river.

Table A2.6 presents a comparison of total miles of streambanks versus miles of eroding streambanks by soil type. All the soils listed are alluvium soils primarily composed of silts and fine sands and have similar texture characteristics. Because of the similar texture characteristics, no individual soil type appears to be more susceptible to erosion than another.

Table A2.1 - Miles of Bank versus Miles of Bank Erosion - Cuyahoga River (river mile 13.8 to 40.25)

	Natural Streambanks (miles)	Modified Streambanks (miles)	Total (miles)
Miles of Bank	52.3	0.7	53.0
Miles of Bank Erosion	14.3	0.1	14.4

Table A2.2 - Estimated Volume of Annual Streambank Erosion - Cuyahoga River (river mile 13.8 to 40.25)

River Section (by river mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) [1/]
13.8 to 15.1	14-1	500	1.5	11	306
	14-2	1,000	0.5	9	167
	14-3	800	1.5	10	444
	14-4	1,000	0.5	9	167
		3,300			1,084
15.1 to 16.0	15-1	600	0.7	8	124
	15-2	1,400	0.7	8	290
		2,000			414
16.0 to 17.0	16-1	900	1.5	5	250
	16-2	700	0.3	8	62
		1,600			312
17.0 to 18.0	17-1	300	1.0	15	167
	17-2	800	0.5	8	119
	17-3	800	0.5	7	104
		1,900			390
18.0 to 19.0	18-1	1,400	1.5	9	700
	18-2	900	0.4	8	107
	18-3	500	1.0	9	167
	18-4	500	0.5	10	93
	18-5	600	1.5	9	300
		3,900			1,367
19.0 to 20.0	19-1	600	1.5	18	600
	19-2	1,200	1.5	14	933
	19-3	900	1.0	13	433
		2,700			1,966
20.0 to 21.0	20-1	500	0.1	10	19
		500			19
21.0 to 22.0	-	None			None

Table A2.2 - Estimated Volume of Annual Streambank Erosion - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) 1/
22.0 to 25.0	22-1	600	4.0	4	356
	22-2	2,700	0.2	8	160
	22-3	1,300	1.0	8	385
	22-4	500	4.0	8	593
	22-5	700	3.5	8	726
	22-6	2,000	0.2	8	118
	22-7	1,300	1.0	8	385
	23-1	1,300	0.2	8	77
	23-2	500	1.5	9	250
	23-3	900	0.2	7	47
	23-4	600	0.3	6	40
	23-5	600	2.5	8	444
	23-6	300	2.0	8	178
	23-7	1,300	0.2	6.5	63
	23-8	1,800	2.0	8	1,067
	23-9	900	1.0	7	233
	23-10	600	1.5	7	233
	23-11	600	2.0	8	356
	23-12	500	0.2	8	30
	23-13	1,100	2.5	10	1,019
	24-1	800	3.0	2	178
	24-2	900	0.2	7	47
	24-3	900	3.0	8	800
		22,700			7,785
25.0 to 26.0	25-1	1,900	1.0	4.6	324
	25-2	600	1.5	6	200
	25-3	1,000	1.5	4	222
	25-4	1,200	0.5	4	89
		4,700			835
26.0 to 27.0	26-1	300	1.5	8	133
	26-2	1,000	1.5	8	444
	26-3	300	5.0	30	1,667
	26-4	300	1.5	5	83
	26-5	600	1.0	8	178
		2,500			2,505

Table A2.2 - Estimated Volume of Annual Streambank Erosion - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) [1]
27.0 to 28.0		None			None
28.0 to 29.0	28-1	1,400	1.5	4	311
	28-2	300	1.5	6	100
		1,700			411
29.0 to 30.0		None			None
30.0 to 32.0	30-1	1,100	1.5	6	367
	30-2	600	0.5	5.5	61
	30-3	600	2.5	4.5	250
	30-4	1,400	2.0	5	519
	31-1	900	3.0	6	600
	31-2	1,200	1.0	5.5	244
	31-3	1,700	0.5	6.3	198
	31-4	600	1.5	4.5	150
		8,100			2,389
32.0 to 33.0	32-1	400	0.5	7.5	56
	32-2	1,500	2.5	5	694
	32-3	800	0.1	4.5	13
	32-4	500	1.5	17	472
	32-5	600	0.2	5	22
	32-6	300	2.0	8	178
	32-7	700	1.5	3.5	136
	32-8	800	0.1	5	15
	32-9	600	0.2	5	22
		6,200			1,608
33.0 to 34.0	33-1	400	0.3	7	31
	33-2	600	0.5	7	78
	33-3	500	0.5	7	65
	33-4	300	0.1	6	7
	33-5	200	0.3	9	20
		2,000			201

Table A2.2 - Estimated Volume of Annual Streambank Erosion - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) [1/]
34.0 to 35.0	34-1	200	0.1	7	5
	34-2	500	1.5	9	250
	34-3	400	0.2	10	30
	34-4	300	0.1	7	8
	34-5	100	0.2	8	6
		1,500			299
35.0 to 36.0	35-1	300	2.0	7	16
	35-2	800	0.4	8	95
	35-3	400	0.2	8	24
	35-4	300	0.4	8	36
	35-5	500	0.5	8	74
	35-6	300	1.0	8	89
	35-7	400	0.2	8	24
	35-8	400	0.1	8	119
	35-9	400	0.2	12	36
		3,800			513
36.0 to 37.0	36-1	200	0.5	8	30
	36-2	200	0.1	8	6
	36-3	300	0.2	12	27
	36-4	700	1.0	7	181
		1,400			244
37.0 to 38.0	37-1	300	0.3	15	50
	37-2	600	0.2	10	44
	37-3	300	0.5	8	44
		1,200			138
38.0 to 39.0	38-1	300	0.5	8	44
	38-2	300	0.2	7	16
	38-3	700	1.0	8	207
	38-4	100	1.0	30	111
		1,400			378

Table A2.2 - Estimated Volume of Annual Streambank Erosion - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of 1/ Annual Streambank Erosion (cy/yr)
39.0 to 40.25	39-1	400	0.5	6	89
	39-2	500	1.0	25	463
	39-3	400	1.0	8	119
	39-4	400	0.3	11	49
	40-1	1,500	0.2	13	144
		3,200			864
Total		76,300			23,712 say 24,000 (or 36,000 tons/yr 2/)

1/ Annual volume of streambank erosion = length of eroding reach X average rate of annual lateral recession X average bank height.

2/ Assumed unit weight of 110 lbs. per cubic foot.

Table A2.3 - Location of Trash and Bedload Bar Buildup Where It Increases the Rate of Annual Lateral Recession - Cuyahoga River (river mile 13.8 to 40.25)

Location of Trash or Bedload Bar Buildup by River Mile	Eroding Reach Affected	Existing Rate of Annual Lateral Recession (feet/year)
19.6 2/	19-3	1.0
26.2 2/	26-4	1.5
31.5 1/	31-4	1.5
32.5 1/	32-2	2.5

1/ Trash Buildup

2/ Bedload Bar Buildup

Table A2.4 - Areas Where Streambanks Have Been Lowered by Topsoil Stripping Operations - Cuyahoga River (river mile 13.8 to 40.25)

Left Bank		Right Bank	
River Mile	Length (feet)	River Mile	Length (feet)
15.5	500	24.3	800
16.2	900		
24.4	300		
25.2	300		
25.3	300		
25.7	400		

Table A2.5 - Miles of Bank versus Miles of Bank Erosion by Adjacent Land Use - Cuyahoga River (river mile 13.8 to 40.25)

Land Use	Total Streambanks (miles)	Eroding Streambanks (miles)
Cropland Land	3.8	2.5
Pasture	0.2	0.2
Forest	38.0	7.4
Urban	6.2	1.1
Other 1/	4.8	3.2
Total	53.0	14.4

1/ Cut and fill areas, roads, and small farmsteads.

Table A2.6 - Miles of Bank versus Miles of Bank Erosion by Soil Type - Cuyahoga River (river mile 13.8 to 40.25)

Soil Type 1/	Total Streambanks (miles)	Eroding Streambanks (miles)
Chagrin Silt Loam	42.1	12.2
Holly Silt Loam (Alkaline)	3.4	0.6
Conotton-Oshtemo Complex	0.9	0
Berks Silt Loam	0.8	0
Chagrin-Urban Land Complex	0.9	0
Tioga Loam	2.8	0.7
Cut and Fill Land	1.9	0.7
Jimtown Loam	0.1	0.1
Fitchville Silt Loam	0.1	0.1
Total	53.0	14.4

1/ Soil type obtained from published soil surveys made by the SCS and ODNR, Division of Lands and Soil.

(b) Tributaries Studied to the USGS Sediment Gage (Chippewa Creek, Furnace Run, Yellow Creek, and Mud Brook) - There are 30,200 feet (5.7 miles) of streambanks that were inventoried for this report on the tributaries studied to the USGS sediment gage. As shown on Table A2.7, of the 30,200 feet of streambanks studied only 9,100 feet (1.7 miles), or 30 percent, are actively eroding. Chippewa Creek has the lowest total footage of streambank erosion (200 feet), and Furnace Run has the highest (5,200 feet). Mud Brook has the highest percentage of eroding streambanks versus total streambanks (85 percent).

The location of the eroding streambanks are shown on Plates A2-8 and A2-9 in Appendix I. Areas with extensive reaches of streambank erosion are located between Riverview Road (stream mile 0.4) and Everett Road (stream mile 1.1) on Furnace Run, between Riverview Road (stream mile 0.2) and the USGS sediment gage (stream mile 0.8) on Yellow Creek and between the Cuyahoga River and the USGS sediment gage (stream mile 0.2) on Mud Brook.

As shown on Table A2.8, the volume of sediment produced from annual streambank erosion is 5,000 cubic yards (or 7,500 tons) per year. The majority of this sediment (94 percent) originates in Furnace Run and Yellow Creek because of the high average rates of annual lateral recession and extensive reaches of bank erosion. Mud Brook, although it also has extensive reaches of streambank erosion (1,700 feet), contributes a small volume of sediment due to its comparatively low rates of annual lateral recession.

Bedload bar buildup in Furnace Run and Yellow Creek appears to be the main reason why these two tributaries have high average rates of annual lateral recession. The railroad bridges that cross each tributary constricts the flow of the stream during high flow periods, creating a backwater effect. This causes the heavier sediment carried by the tributaries (coarse sand and gravel) to settle out upstream of the bridges which in turn reduces the channel cross-section. During periods of normal flow, the reduced cross-section causes an increase in flow velocity and a corresponding increase in the erosion force of the stream. Since the alluvium soils of the streambanks offer less resistance to erosion than the bedload bars, this increased erosion force is directed towards the streambanks, resulting in higher rates of annual lateral recession. The same situation occurs in Chippewa Creek except that the Cleveland Metroparks excavates the bedload material before it causes increased streambank erosion. The locations where bedload bar buildup increases the rate of annual lateral recession in Furnace Run and Yellow Creek are shown on Table A2.9.

The high rates of annual lateral recession in Furnace Run and Yellow Creek are also causing damage to the abutments to the B&O railroad bridges over the tributary channels. Based on the estimated annual lateral recession rate for eroding reach 0-2 on Furnace Run (2 feet per year) significant damage to the south abutment will occur within 5 years. The same situation occurs in Yellow Creek at eroding reach 0-2 (with an estimated annual lateral recession rate of 3 feet per year) where significant damage to the north abutment can again be expected within 5 years.

Table A2.10 presents a comparison of total feet of streambanks versus feet of eroding streambanks by adjacent land use. On Furnace Run, although cropland occurs on only 10 percent of the streambanks, it accounts for 30 percent of the eroding streambanks. On Yellow Creek, 80 percent of the eroding streambanks occur adjacent to other land use (cut and fill areas, roads, and small farmsteads) which account for only 19 percent of the total streambanks. On Mud Brook, urban land use was the only land use encountered, but 85 percent of the streambanks were eroding. It therefore appears that the main problem areas occur adjacent to land uses that disturb or destroy the protective vegetation covering.

Table A2.11 presents a comparison of total feet of streambanks versus feet of eroding streambanks by soil type. As shown on this table, almost all of the eroding streambanks are adjacent to the recent alluvium soil types of Chagrin Silt Loam and Tioga Loam. The characteristics of these two soil types are similar, and they are primarily composed of fine sands and silts. These fine sands and silts offer little resistance to erosion.

Table A2.7 - Feet of Bank versus Feet of Bank Erosion - Tributaries Studied to USGS Sediment Gage

Chippewa Creek (stream mile 0.0 to 0.4)

	Natural Streambanks (feet)	Modified Streambanks (feet)	Total (feet)
Feet of Bank	2,600	1,200	3,800
Feet of Bank Erosion	200	0	200

Furnace Run (stream mile 0.0 to 1.5)

	Natural Streambanks (feet)	Modified Streambanks (feet)	Total (feet)
Feet of Bank	15,500	500	16,000
Feet of Bank Erosion	5,000	200	5,200

Yellow Creek (stream mile 0.0 to 0.8)

	Natural Streambanks (feet)	Modified Streambanks (feet)	Total (feet)
Feet of Bank	8,200	200	8,400
Feet of Bank Erosion	2,000	0	2,000

Mud Brook (stream mile 0.0 to 0.2)

	Natural Streambanks (feet)	Modified Streambanks (feet)	Total (feet)
Feet of Bank	1,000	1,000	2,000
Feet of Bank Erosion	700	1,000	1,700

Table A2.8 - Estimated Volume of Annual Streambank Erosion - Tributaries Studied to the USGS Sediment Gage

Stream Section (by stream mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) 1/
	Chippewa Creek (stream mile 0.0 to 0.4)				
0.0 to 0.4	0-1	200	0.2	4.0	7
		200			7
	Furnace Run (stream mile 0.0 to 1.5)				
0.0 to 1.5	0-1	200	1.5	10	111
	0-2	200	2.0	8	119
	0-3	500	2.5	7	324
	0-4	700	1.5	5	194
	0-5	1,000	1	7	259
	0-6	300	1.5	6	100
	0-7	200	1.0	7.5	56
	0-8	500	3.0	6.5	361
	0-9	300	0.5	3.5	19
	0-10	300	1.0	6	67
	1-1	200	1.0	25	185
	1-2	300	1.5	7	117
	1-3	500	1.0	10.5	194
		5,200			2,106
	Yellow Creek (stream mile 0.0 to 0.8)				
0.0 to 0.8	0-1	300	2.0	5.5	122
	0-2	400	3.0	9.5	422
	0-3	600	2.5	7	389
	0-4	100	0.5	4	7
	0-5	400	3.0	17	756
	0-6	200	3.0	50	1,111
		2,000			2,907
	Mud Brook (stream mile 0.0 to 0.2)				
0.0 to 0.2	0-1	200	0.5	5	37
	0-2	300	1.0	6	67
	0-3	200	0.5	5	37
	0-4	200	0.5	5	37
	0-5	500	0.5	8	148
	0-6	300	0.2	5	11
		1,700			337
Total		9,100			5,357 say 5,000 (or 7,500 tons/yr 2/)

1/ Annual volume of streambank erosion = length of eroding reach X average rate of annual lateral recession X average bank height.

2/ Assumed unit weight of 110 lbs. per cubic foot.

Table A2.9 - Location of Bedload Bar Buildup Where It Increases the Rate of Annual Lateral Recession - Tributaries Studied to USGS Gage

Location of Bedload Bar Buildup by Stream Mile	Eroding Reach Affected	Existing Rate of Annual Lateral Recession (feet/year)
Chippewa Creek (stream mile 0.0 to 0.4)		
None		
Furnace Run (stream mile 0.0 to 1.5)		
0.4 1/	0-2	2.0
0.4 1/	0-8	3.0
0.6	0-9	0.5
0.7	0-4	1.5
0.9	0-5	1.0
Yellow Creek (stream mile 0.0 to 0.8)		
0.3	0-2	3.0
0.6	0-5	3.0
Mud Brook (stream mile 0.0 to 0.2)		
None		

1/ Same sediment bar affects two different eroding reaches.

Table A2.10 - Feet of Bank versus Feet of Bank Erosion by Adjacent Land Use - Tributaries Studied to USGS Sediment Gage

Land Use	Total Streambanks (feet)	Eroding Streambanks (feet)
Chippewa Creek (stream mile 0.0 to 0.4)		
Cropland	0	0
Pasture	0	0
Forest	2,300	0
Urban	200	200
Other 1/	1,300	0
Total	3,800	200
Furnace Run (stream mile 0.0 to 1.5)		
Cropland	1,700	1,500
Pasture	0	0
Forest	7,300	2,300
Urban	2,300	700
Other 1/	4,700	700
Total	16,000	5,200
Yellow Creek (stream mile 0.0 to 0.8)		
Cropland	0	
Pasture	0	
Forest	4,900	100
Urban	1,900	300
Other 1/	1,600	1,600
Total	8,400	2,000
Mud Brook (stream mile 0.0 to 0.2)		
Cropland	0	0
Pasture	0	0
Forest	0	0
Urban	2,000	1,700
Other 1/	0	0
Total	2,000	1,700

1/ Cut and fill areas, roads, and small farmsteads.

Table A2.11 - Feet of Bank versus Feet of Bank Erosion by Adjacent Soil Type - Tributaries Studied to USGS Sediment Gage

Soil Type 1/	Total Streambanks (feet)	Eroding Streambanks (feet)
Chippewa Creek (stream mile 0.0 to 0.4)		
Chagrin Silt Loam	200	0
Cut and Fill Land	1,200	0
Tioga Loam	2,400	200
Total	3,800	200
Furnace Run (stream mile 0.0 to 1.5)		
Chagrin Silt Loam	3,600	1,300
Tioga Loam	6,500	3,400
Lobdell Silt Loam	5,600	500
Bridges and Conduits	300	0
Total	16,000	5,200
Yellow Creek (stream mile 0.0 to 0.8)		
Chagrin Silt Loam	1,400	0
Tioga Loam	5,600	2,000
Lobdell Silt Loam	1,200	0
Closed Conduit	200	0
Total	8,400	2,000
Mud Brook (stream mile 0.0 to 0.2)		
Chagrin Silt Loam	2,000	1,700
Total	2,000	1,700

1/ Soil type obtained from published soil surveys made by the SCS and ODNR, Division of Lands and Soil.

(c) Brandywine Creek (stream mile 0.0 to 11.6) - There are 29.6 miles of streambanks along Brandywine Creek and Indian Creek (the major tributary to Brandywine Creek) that were inventoried for this report. As shown on Table A2.12, 2.5 miles of streambanks, or 8 percent, are actively eroding. The location of these eroding streambanks are shown on Plates A2-8 and A2-10 in Appendix I. The majority of the eroding streambanks occur in the first 2 miles of Brandywine Creek and at one location on Indian Creek (stream mile 2.2).

As shown on Table A2.13, the volume of sediment produced from annual streambank erosion on Brandywine Creek is 5,000 cubic yards (or 7,500 tons) per year. Almost 84 percent of this volume occurs between stream mile 1.0 and 2.0. In particular, reach 1-7 contributes 3,000 cubic yards per year, or 60 percent of the total volume for Brandywine Creek. The streambank at this location is approximately 80 feet high and as the stream erodes the toe of its bank (at an annual rate of 3.5 feet per year), the entire face of the bank slips into the stream. Table A2.14 indicates that the volume of sediment produced from annual streambank erosion on Indian Creek is only 200 cubic yards (or 300 tons) per year and is insignificant.

Table A2.15 presents a comparison of total miles of streambanks versus miles of eroding streambanks by adjacent land use. While 57 percent of the streambanks are forested, they account for only 28 percent of the eroding streambanks. The other 72 percent of the eroding streambanks are adjacent to urban and other land uses which both disturb the protective vegetation covering. This situation is more pronounced in Brandywine Creek because of the unusual activities and development of the Brandywine Ski Resort.

Table A2.16 presents a comparison of total miles of streambanks versus miles of eroding streambanks by soil type. It does not appear that any particular soil type is eroding more than another except where the creek flows through shale outcroppings where no streambank erosion occurs.

Table A2.12 - Miles of Bank versus Miles of Bank Erosion - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively)

	Natural Streambanks (miles)	Modified Streambanks (miles)	Total (miles)
Miles of Bank	25.0	4.6	29.6
Miles of Bank Erosion	1.7	0.8	2.5

Table A2.13 - Estimated Volume of Annual Streambank Erosion - Brandywine Creek (stream mile 0.0 to 11.6)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) 1/
0.0 to 1.0	0-1	1,200	0.1	4	18
	0-2	200	0.4	6	18
	0-3	100	0.4	5	7
	0-4	300	0.3	5	17
	0-5	500	1.5	12	333
	0-6	1,600	0.1	5	30
	0-7	300	0.1	6	7
	0-8	400	0.4	6	36
	0-9	200	0.4	5	15
	0-10	200	0.4	5	15
	0-11	400	1.0	6	89
		5,400			585
1.0 to 2.0	1-1	200	1.0	8	59
	1-2	400	1.0	30	444
	1-3	700	1.0	11	285
	1-4	400	1.0	7	104
	1-5	200	1.0	5	74
	1-6	200	0.4	3	22
	1-7	300	3.5	80	3,111
		2,400			4,099
2.0 to 8.0		None			None
8.0 to 9.0	8-1	400	0.3	7	31
	8-2	400	0.3	7	31
		800			62
9.0 to 10.0	9-1	700	0.4	7	73
	9-2	700	0.4	7	73
		1,400			146
10.0 to 11.6		None			None
Total		10,000			4,892 say 5,000 (or 7,500 tons/yr 2/)

1/ Annual volume of streambank erosion = length of eroding reach X average rate of annual lateral recession X average bank height.

2/ Assumed unit weight of 110 lbs. per cubic foot.

Table A2.14 - Estimated Volume of Annual Streambank Erosion - Indian Creek (stream mile 0.0 to 3.2)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) [1]
0.0 to 2.0		None			None
2.0 to 3.0	2-1	1,500	0.3	6	100
	2-2	1,500	0.3	6	100
		3,000			200
3.0 to 3.2		None			None
Total		3,000			200 (or 300 tons/yr[2])

1/ Annual volume of streambank erosion = length of eroding reach X average rate of annual lateral recession X average bank height.

2/ Assumed unit weight of 110 lbs. per cubic foot.

Table A2.15 - Miles of Bank versus Miles of Bank Erosion by Adjacent Land Use - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively)

Land Use	Total Streambanks (miles)	Eroding Streambanks (miles)
Cropland	0	0
Pasture	0	0
Forest	16.9	0.7
Urban	7.5	0.9
Lake	2.1	0
Other 1/	3.1	0.9
Total	29.6	2.5

1/ Cut and fill areas, roads, and small farmsteads.

Table A2.16 - Miles of Bank versus Miles of Bank Erosion by Soil Type - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively)

Soil Type [1]	Total Streambanks (miles)	Eroding Streambanks (miles)
Chagrin Silt Loam	1.1	0.5
Lobdell Silt Loam	14.8	0.9
Chili Gravelly Loam	0.9	0.3
Ellsworth Silt Loam	0.5	0.2
Holly Silt Loam	8.7	0.6
Cut and Fill Land	0.6	0
Shale Rock Land	0.9	0
Lakes	2.1	0
Total	29.6	2.5

[1] Soil type obtained from published soil surveys made by the SCS and ODNR, Division of Lands and Soil.

(d) Tinkers Creek (stream mile 0.0 to 27.3) - There are 54.6 miles of streambanks along Tinkers Creek that were inventoried for this report. As shown on Table A2.17, 4.1 miles of streambanks, or 8 percent, are actively eroding. The location of these eroding streambanks are shown on Plates A2-8, A2-11, and A2-12 in Appendix I. Areas with extensive reaches of streambank erosion are located between stream mile 0.0 to 2.0, stream mile 11.5 to 12.0, and stream mile 14.1 to 14.5. No streambank erosion occurs for the remaining 12.8 miles of Tinkers Creek upstream of stream mile 14.5.

As shown on Table A2.18, the volume of sediment produced from annual streambank erosion is 18,000 cubic yards (or 27,000 tons) per year. Almost 90 percent of this volume occurs between stream mile 1.0 to 2.0 and stream mile 11.0 to 12.0. In particular reach 1-6 contributes 13,000 cubic yards, or 72 percent of the total volume for Tinkers Creek. The streambank at this location is approximately 70 feet high, and the average rate of annual lateral recession is 10 feet per year. This recession rate was the highest for any reach in the entire study area. The other eroding areas along Tinkers Creek have lower average rates of annual lateral recession and produce a corresponding lower volume of sediment.

Bedload bar buildup on Tinkers Creek at stream mile 0.1 contributes to the high rate of annual lateral recession in reach 0-5 (3 feet/yr). The canal aqueduct that crosses Tinkers Creek at this location constricts the flow of the stream during high flow periods which allows the heavier sediment to settle upstream of the aqueduct and form this bedload bar. During normal flow periods, the reduced channel cross-section causes an increase in flow velocity and a resultant increase in streambank erosion. This situation is aggravated because construction of the power line crossing Tinkers Creek at this location has left the streambank bare, with no protective vegetative covering.

Table A2.19 presents a comparison of total miles of streambanks versus miles of eroding streambanks by adjacent land use. As shown on this table, man-disturbed areas (cropland, urban, and other land uses) account for 56 percent of the eroding streambanks but only 11 percent of the total streambanks. The other eroding streambanks are forested.

Table A2.20 presents a comparison of total miles of streambanks versus miles of eroding streambanks by soil type. As was the case with Furnace Run and Yellow Creek, Tioga Silt Loam accounts for the majority of the eroding streambanks (60 percent). Cut and fill land accounts for an additional 25 percent of the eroding streambanks even though it comprises only 2 percent of the total streambanks.

Table A2.17 - Miles of Bank versus Miles of Bank Erosion - Tinkers Creek (stream mile 0.0 to 27.3)

	Natural Streambanks (miles)	Modified Streambanks (miles)	Total (miles)
Miles of Bank	51.5	3.1	54.6
Miles of Bank Erosion	2.9	1.2	4.1

Table A2.18 - Estimated Volume of Annual Streambank Erosion - Tinkers Creek (stream mile 0.0 to 27.3)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion [1/] (cy/yr)
0.0 to 1.0	0-1	500	0.1	9	17
	0-2	100	0.2	3	2
	0-3	700	0.5	5	65
	0-4	400	0.1	5.5	8
	0-5	300	3.0	5.5	183
	0-6	400	0.1	6	9
	0-7	100	1.5	6	33
	0-8	700	1.0	5	130
	0-9	2,000	1.0	4.8	356
		5,200			803
1.0 to 2.0	1-1	1,000	1.0	5	185
	1-2	800	0.5	5	74
	1-3	600	0.5	4	44
	1-4	1,000	0.1	5	19
	1-5	300	0.1	5	6
	1-6	500	10	70	12,963
	1-7	300	1.0	4.5	50
	1-8	1,100	1.0	4	163
		5,600			13,504
2.0 to 3.0	2-1	700	2.0	12	622
		700			622
3.0 to 4.0	3-1	700	0.5	4	52
		700			52
4.0 to 5.0	4-1	500	1.0	4	74
	4-2	700	0.5	4.5	58
	4-3	400	1.0	4.5	67
		1,600			199
5.0 to 6.0		None			None
6.0 to 7.0	6-1	100	1.0	10	37
		100			37
7.0 to 11.0		None			None

Table A2.18 - Estimated Volume of Annual Streambank Erosion - Tinkers Creek (stream mile 0.0 to 27.3) (Cont'd)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length of Eroding Reach (feet)	Average Rate of Annual Lateral Recession (feet/yr)	Average Bank Height (feet)	Volume of Annual Streambank Erosion (cy/yr) [1/]
11.0 to 12.0	11-1	2,500	1.0	7	648
	11-2	2,500	1.0	20	1,852
		5,000			2,500
12.0 to 14.0		None			None
14.0 to 15.0	14-1	400	0.5	5	37
	14-2	400	0.3	5	22
	14-3	600	1.5	7	233
	14-4	600	0.3	6	40
	14-5	300	0.3	5	17
	14-6	500	0.3	5	28
		2,800			377
15.0 to 27.3		None			None
Total		21,700			18,094 say 18,000 (or 27,000 tons/yr [2/])

1/ Annual volume of streambank erosion = length of eroding reach X average rate of annual lateral recession X average bank height.

2/ Assumed unit weight of 110 lbs. per cubic foot.

Table A2.19 - Miles of Bank versus Miles of Bank Erosion by Adjacent Land Use - Tinkers Creek (stream mile 0.0 to 27.3)

Land Use	Total Streambanks (miles)	Eroding Streambanks (miles)
Cropland	0.2	0.1
Pasture	0	0
Forest	48.5	1.8
Urban	4.3	2.0
Other 1/	1.6	0.2
Total	54.6	4.1

1/ Cut and fill areas, roads, and small farmsteads.

Table A2.20 - Miles of Bank versus Miles of Bank Erosion by Soil Type - Tinkers Creek (stream mile 0.0 to 27.3)

Soil Type 1/	Total Streambanks (miles)	Eroding Streambanks (miles)
Chagrin Silt Loam	8.8	0.1
Tioga Silt Loam	13.1	2.4
Euclid Silt Loam	0.4	0.1
Berks Silt Loam	3.8	0
Hornell Silt Loam	0.2	0
Holly Silt Loam	25.9	0.2
Orville Silt Loam	1.4	0.3
Cut and Fill Land	1.0	1.0
Total	54.6	4.1

1/ Soil type obtained from published soil surveys made by the SCS and ODNR, Division of Lands and Soil.

(e) Summary and General Conclusions - There were approximately 143 miles of streambanks in the study area which were studied for this report. This includes both banks so that in one stream mile there were two streambank miles. As shown on Table A2.21, of the 143 miles of streambanks studied, only 22.7 miles, or 16 percent, were actively eroding. The location of these eroding streambanks are shown on Plates A2-8 to A2-12 in Appendix I.

Table A2.22 presents a summary of the estimated volume of sediment produced from annual streambank erosion. As indicated, annual streambank erosion produces about 52,000 cubic yards of sediment (or 78,000 tons) per year. The Cuyahoga River (between river mile 13.8 and 40.25) contributes the largest amount of sediment (approximately 24,000 cubic yards per year or 46 percent of the total volume) followed by Tinkers Creek (18,000 cubic yards per year or 35 percent of the total volume). Chippewa Creek and Mud Brook produce the least amount of sediment (7 cubic yards per year and 337 cubic yards per year, respectively) and are insignificant.

Several areas of the streams studied produce the majority of the sediment derived from annual streambank erosion. These areas are as follows:

(1) Cuyahoga River:	river mile 13.8 to 15.1
	river mile 18.0 to 20.0
	river mile 22.0 to 25.0
	river mile 26.0 to 27.0
	river mile 30.0 to 33.0
(2) Furnace Run:	stream mile 0.0 to 1.5
(3) Yellow Creek:	stream mile 0.0 to 0.8
(4) Brandywine Creek:	stream mile 1.0 to 2.0
(5) Tinkers Creek	stream mile 1.0 to 2.0
	stream mile 11.0 to 12.0

These areas produce 44,000 cubic yards of sediment per year or 85 percent of the total volume from annual streambank erosion.

Two reaches, reach 1-7 in Brandywine Creek and reach 1-6 in Tinkers Creek, were identified as the highest producers of sediment from annual streambank erosion in the study area. High rates of annual lateral recession (3.5 feet per year and 10 feet per year, respectively) in conjunction with bank heights in excess of 70 feet produce 16,000 cubic yards of sediment per year, or 30 percent of the total volume for the entire study area. The majority of the other eroding reaches in the study area had bank heights that averaged about 8 feet and annual lateral recession rates between 0.1 to 1.5 feet per year.

Trash (dead trees, construction debris, etc.) and bedload bar buildup is a contributing factor to the high rates of annual lateral recession at several locations. Trash buildup gouges the bank as it becomes lodged and deflects the stream flow either into the toe of the bank, causing undercutting, or into the

river bed, causing scouring. Bedload bar buildup reduces the channel cross-section, causing an increase in flow velocity and a corresponding increase in the erosion force of the stream. Since the alluvium soils of the streambanks offer less resistance to erosion than the bedload bars, this increased erosion force acts against the streambanks resulting in higher rates of annual lateral recession.

There are also several locations along the Cuyahoga River where topsoil stripping operations have lowered the existing streambank. This allows the river to leave its banks during periods of above-average flow and scour its flood plain. Although the quantity of sediment eroded from the flood plain during periods of overbank flow was not quantified for this report, it is believed to be significant in these areas because the topsoil stripping operation removes the protective vegetative covering.

There are several sites along the Cuyahoga River, Furnace Run, and Yellow Creek where damage to local roads and railroad facilities of the Baltimore and Ohio Railroad will occur in the near future because of the high rates of annual lateral recession at these locations. Local roads that are endangered occur at river mile 24.6 and 35.0. Damage to these roads can be expected within 20 and 15 years, respectively. Damage to railroad facilities at river mile 14.8 and 26.2 on the Cuyahoga River, stream mile 0.4 on Furnace Run and stream mile 0.2 on Yellow Creek can be expected to occur within 10 years, 10 years, 5 years, and 5 years, respectively. Damage to these railroad facilities will adversely impact on the industries located in Cleveland since the B&O railroad system is one of the major trunk lines serving the city of Cleveland.

A correlation can be made between adjacent land use and streambank erosion. Streambanks adjacent to land uses that disturb or destroy the protective vegetation covering (cropland and other land (cut and fill areas, roads, and small farmsteads)) are more susceptible to erosion than streambanks adjacent to forest land. The forest vegetation acts as a buffer, absorbing part of the erosion force of the stream before it comes in contact with the soil surface. There are, however, streambanks that are forested that are also eroding. They generally occur on the outside of sharp bends in the stream where the erosive forces of the streams are greater. These forces generally cause streambank erosion no matter what type of vegetation is present.

No correlation could be made between streambank erosion and soil type. The majority of the soils encountered were alluvium soils primarily composed of silts and fine sands and have similar texture characteristics. Because of the similar texture characteristics, no individual soil type appeared to be more susceptible to erosion than another.

As previously indicated, annual streambank erosion produces about 52,000 cubic yards of sediment annually. A portion of this sediment, however, settles out before it reaches Cleveland Harbor. This sediment either forms bedload bars, which usually contribute to the high rates of annual lateral recession, or is deposited on the inside of bends in the streams. Sieve analyses for the soil types encountered in the study area, as reported in the Soil Survey Reports prepared by the Soil Conservation Service and the Ohio

Department of Natural Resources, Division of Lands and Soil, indicated that the soils encountered had a proportion of particles with a diameter of one-quarter inch or larger of about 10 percent. It is assumed that these particles are too heavy to be transported by the Cuyahoga River to Cleveland Harbor and thus settle out. Therefore, it is estimated that about 10 percent of the sediment produced from annual streambank erosion, or 5,000 cubic yards, settles out before it reaches Cleveland Harbor. This assumption appears reasonable since no major areas of deposition were located while conducting the streambank data survey.

As discussed in Section B - "Problem Identification" of the Main Report, the Corps of Engineers annually dredges about 800,000 cubic yards of sediment from the navigation channel and lakefront harbor at Cleveland. In addition, private dock owners annually dredge an additional 60,000 cubic yards of sediment. Therefore, the total volume of sediment annually dredged is 860,000 cubic yards. By comparing the volume of sediment produced from annual streambank erosion which reaches Cleveland Harbor (52,000 cubic yards - 5,000 cubic yards, or 47,000 cubic yards) with the 860,000 cubic yards of sediment dredged, it can be concluded that annual streambank erosion accounts for only about 5 percent of the sediment dredged and is insignificant. Therefore, other sources of sediment must be identified if an effective sediment control program is to be implemented that would significantly reduce dredging at Cleveland Harbor.

Table A2.21 - Miles of Bank versus Miles of Bank Erosion - Total Channel Component Study Area 1/

	Natural Streambanks (miles)	Modified Streambanks (miles)	Total (miles)
Miles of Bank	134	8.9	142.9
Miles of Bank Erosion	20.4	2.3	22.7

1/ Cuyahoga River (river mile 13.8 to 40.25), Chippewa Creek (stream mile 0.0 to 0.4), Furnace Run (stream mile 0.0 to 1.5), Yellow Creek (stream mile 0.0 to 0.8), Mud Brook (stream mile 0.0 to 0.2), Brandywine Creek (0.0 to 11.6, including Indian Creek - stream mile 0.0 to 3.2) and Tinkers Creek (stream mile 0.0 to 27.3).

Table A2.22 - Estimated Volume of Annual Streambank Erosion - Total Channel Component Study Area

Channel Component	Total Annual Streambank Erosion (cy/yr)
Cuyahoga River (river mile 13.8 to river mile 40.25)	23,712
Chippewa Creek (stream mile 0.0 to stream mile 0.4)	7
Furnace Run (stream mile 0.0 to stream mile 1.5)	2,106
Yellow Creek (stream mile 0.0 to stream mile 0.8)	2,907
Mud Brook (stream mile 0.0 to stream mile 0.2)	337
Brandywine Creek (stream mile 0.0 to stream mile 11.6 and Indian Creek)	5,092
Tinkers Creek (stream mile 0.0 to stream mile 27.3)	18,094
Total	52,255 say 52,000 (or 78,000 tons/yr[1/])

1/ Assumed unit weight of 110 lbs. per cubic foot.

(2) Meander Changes - As previously defined, meander changes are areas where the river has formed a new channel. Although they may form at any time, they normally occur during the high flow season (March through June). When meander changes occur, a sediment load is introduced into the system equal to the dimensions of the new channel formed.

In order to predict where future meander changes would occur, previous meander changes were identified and studied to gain an understanding of the phenomenon. Plates A2-6 and A2-7 in Appendix I (Changes in River Location) were evaluated, and seven major meander changes were identified that occurred between the years 1938 to 1977. The location of these meander changes are shown on Plates A2-6 and A2-7 and on Table A2.23. Table A2.23 also indicates that these meander changes produced approximately 110,000 cubic yards of sediment when they formed.

The meander changes that occurred at river miles 31.1 and 32.9 formed new meander loops. Physical evidence (deposition areas) indicated that these meander loops formed as a result of the sediment load from Furnace Run. When the sediment-laden flow from Furnace Run entered the Cuyahoga River, its velocity was reduced. This reduced flow velocity allowed the heavier sediment (gravel and coarse sand) to settle and form bedload bars. These bedload bars in turn blocked the original river course and forced the river to form a new channel.

The remaining existing meander changes formed when the Cuyahoga River cut a new channel through the neck of an existing meander loop. In meander loops, the erosive force of the river is directed against the outside banks of the curve resulting in high bank erosion rates. As a result of these high erosion rates, the width of the meander neck narrows during succeeding years. When the width is sufficiently narrow, the river breaches the meander neck and forms a new channel across it. This process is illustrated on Figure A2.3. It is not known why the original meander loops formed although it is probable that they formed as a result of sediment bar formation in the original river channel.

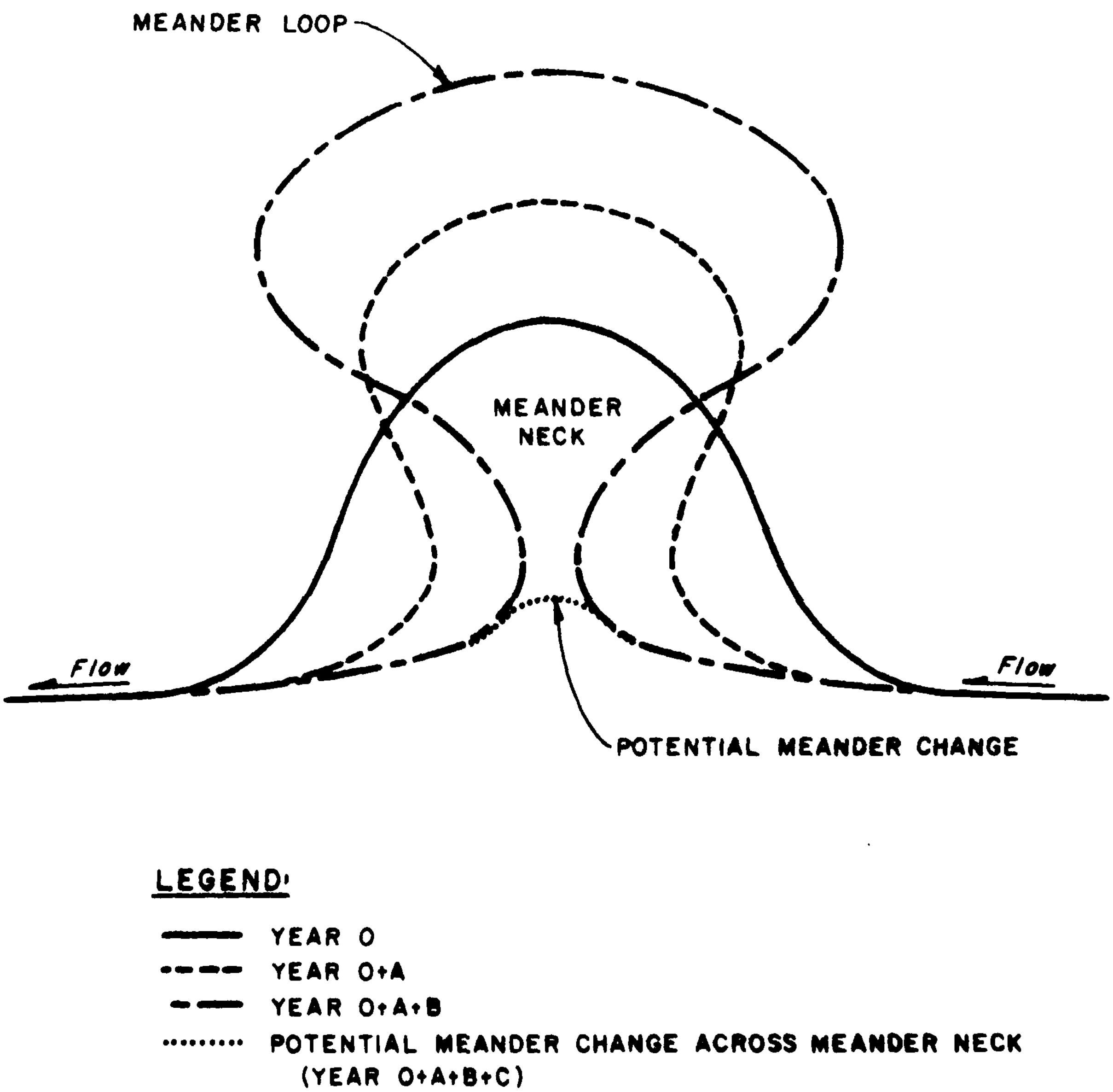
The information gathered from investigating previous meander changes was used to locate potential sites of new meander changes while conducting the streambank survey. All meander loops encountered while conducting the streambank survey were evaluated to see if there was any evidence that the river was attempting to cut a new channel across the meander neck. Six potential sites were identified, and their potential new courses are illustrated on Figures A2.4 to A2.7. (Two different meander changes will occur at river mile 34.8 (Figure A2.5). Meander change (a) will occur first and then meander change (b) will form later.) In all cases, man has disturbed the protective bank vegetative cover which has: (1) increased the rate of bank erosion against the meander neck as identified by the high estimated rates of annual lateral recession at these locations; and (2) created a path of reduced resistance for overland flow across the meander neck. At all six sites, flood plain scour in a confined area across the meander neck was present. The potential course of the river was further defined by debris buildup along either side of the scoured area. This evidence led to the conclusion that the river was cutting a new channel. In addition, at several sites (river miles 23.3,

26.1, and 39.0) the new channel paralleled the river channel in 1938 and is located on the opposite side of the 1938 channel in relation to the present (1977) channel. This indicates that meander changes on the Cuyahoga River tend to form within a defined meander belt.

Table A2.24 presents the calculations that were performed to estimate the quantity of sediment that will be introduced when the meander changes occur. As indicated, 125,000 cubic yards of sediment will be produced. This volume is equivalent to the volume of sediment produced from approximately two and one-half years of annual streambank erosion.

Table A2.23 - Major Meander Changes that Have Occurred in the Past - Cuyahoga River (river mile 13.8 to 40.25)

Location by River Mile	Channel Dimensions of New Channel Formed: Length (feet)	Width (feet)	Depth (feet)	Quantity of Sediment Produced (cubic yards)
14.7	500	60	10	11,111
17.9	800	100	10	29,630
23.0	300	70	8	6,222
24.8	400	70	8	8,296
31.1	1,000	100	8	29,630
32.9	1,000	80	6	17,778
39.3	500	70	8	10,370
Total				113,037 say 110,000

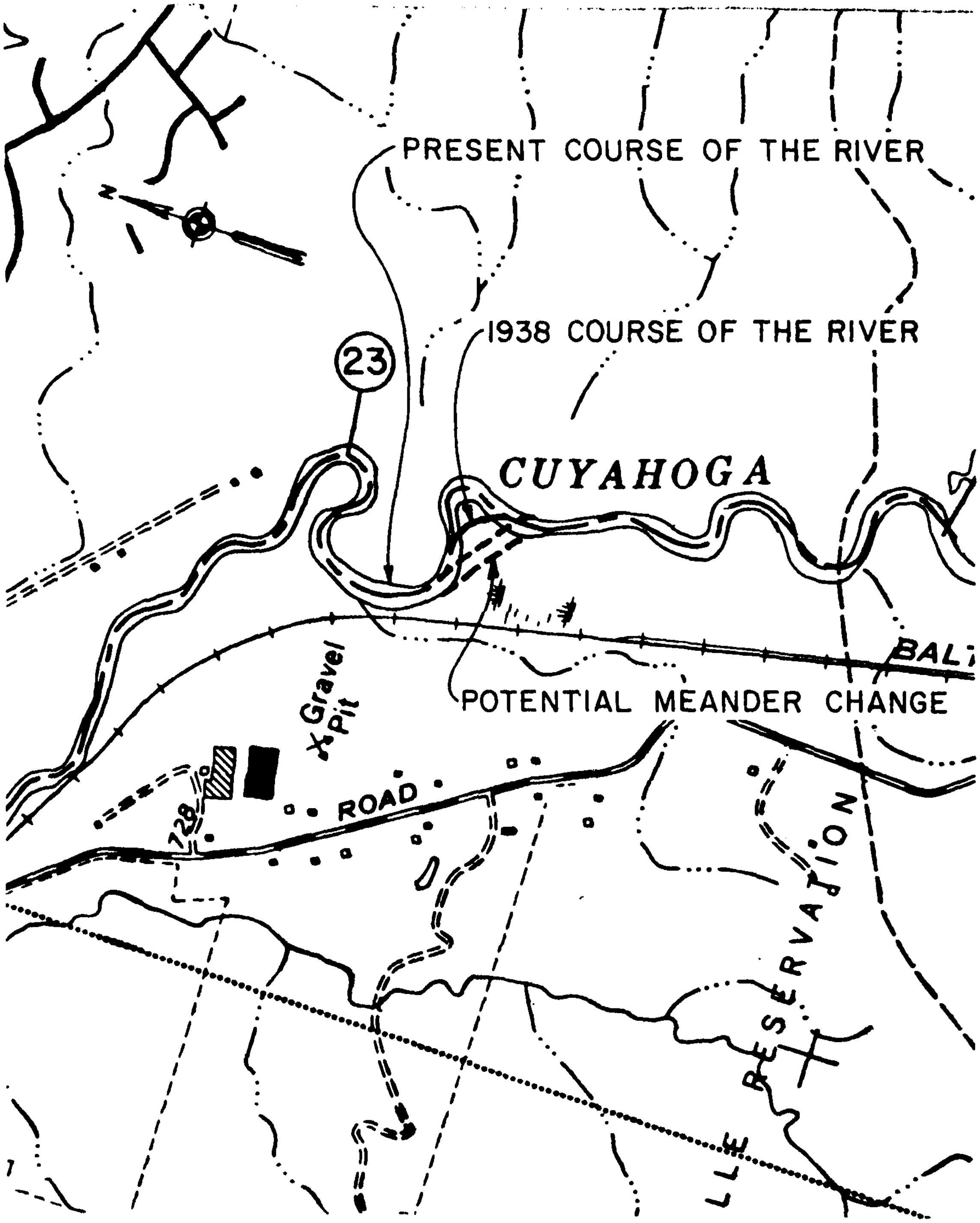


CUYAHOGA RIVER, OHIO
RESTORATION STUDY

MEANDER LOOP SEQUENCE

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A2.3

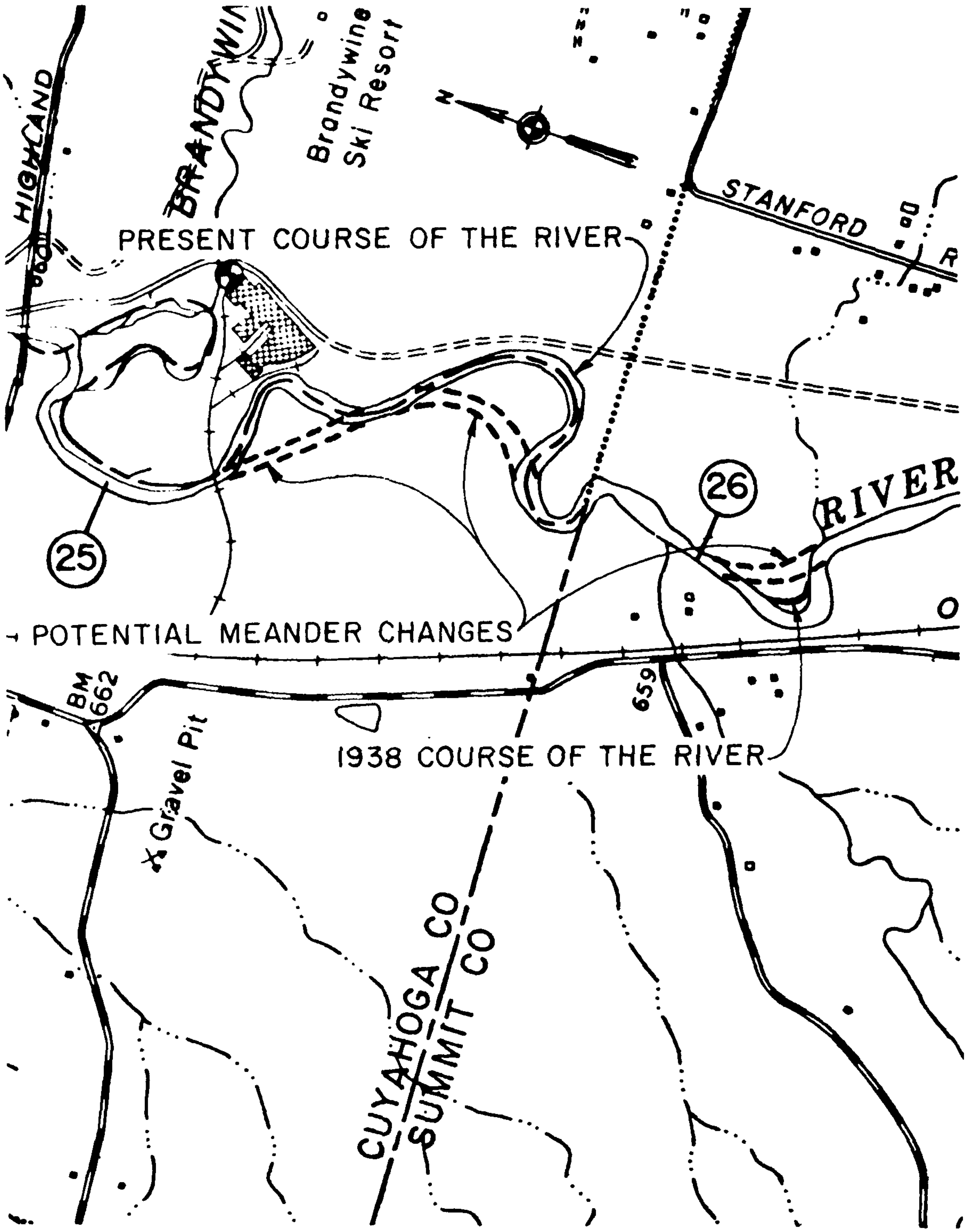


CUYAHOGA RIVER, OHIO
RESTORATION STUDY

POTENTIAL MEANDER CHANGE
AT CUYAHOGA RIVER MILE
23.3

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

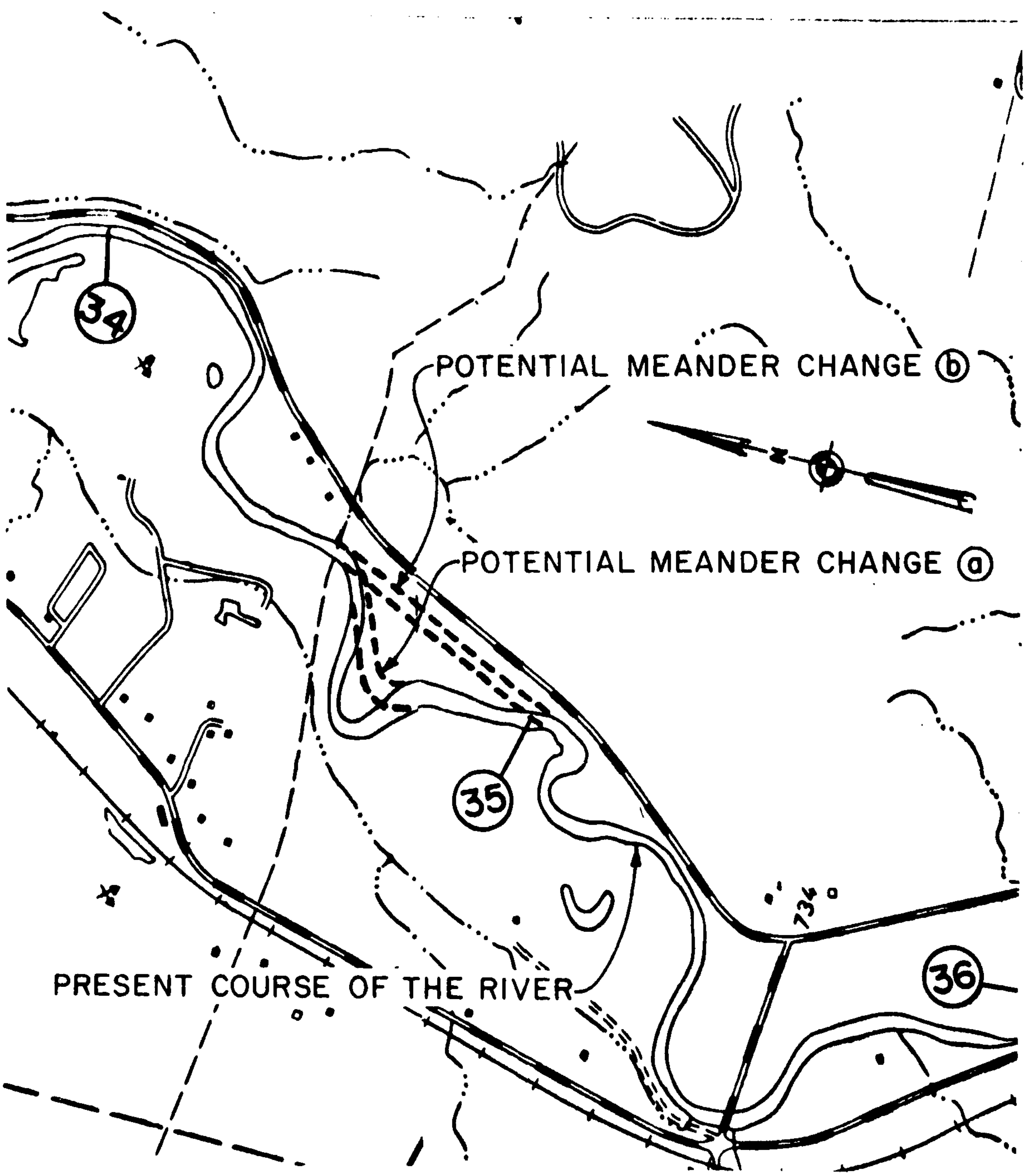
FIGURE A2.4



CUYAHOGA RIVER, OHIO
RESTORATION STUDY
POTENTIAL MEANDER CHANGES AT CUYAHOGA RIVER MILES 25.3, 25.7 AND 26.1

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A2.5

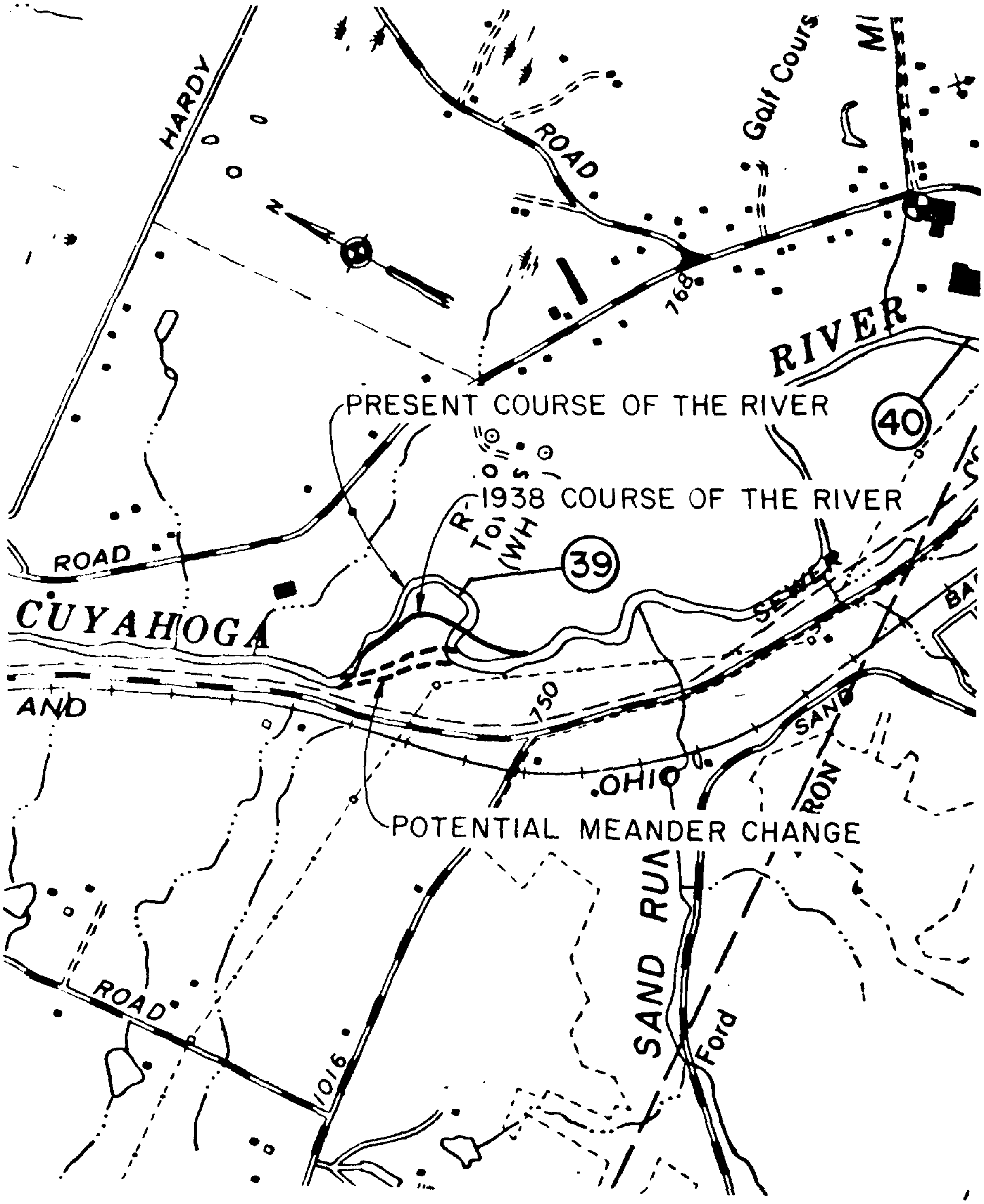


CUYAHOGA RIVER, OHIO
RESTORATION STUDY

POTENTIAL MEANDER CHANGES AT CUYAHOGA RIVER MILE 34.8

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A2.8



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

POTENTIAL MEANDER CHANGE
AT CUYAHOGA RIVER MILE
39.0

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A2.7

Table A2.24 - Potential Meander Changes - Cuyahoga River
(river mile 13.8 to 40.25)

Location by River Mile	Estimated New Channel Dimensions Length (feet)	Width (feet)	Depth (feet)	Quantity of Sediment that Would be Produced (cubic yards)
23.3	500	70	7	9,074
25.3	800	70	6	12,444
25.7	900	70	6	14,000
26.1	500	70	5	6,481
34.8(a)	900	80	8	21,333
34.8(b)	1,400	80	8	33,185
39.0	900	100	8	26,667
Total				123,184 say 125,000

A3. UPLAND WATERSHED COMPONENT

a. GENERAL - The upland watershed component is concerned with gross erosion (dislodgement or detachment of soil particles) of the land surface and delivery of this sediment to a stream channel. For the purpose of this report the sources of sediment have been divided into two areas: (1) sediment produced from diffuse nonpoint sources; and (2) sediment produced from identifiable nonpoint sources. Diffuse nonpoint sources refer to the entire land surface where sheet and rill erosion occurs. Identifiable nonpoint sources refer to those areas where highly visible gully erosion on disturbed areas is taking place. Different methods will be used to identify and quantify the erosion taking place from these two nonpoint source areas. This is detailed in the following sections.

The upland watershed component study area consists of the 303 square-mile drainage area between Independence, OH, (river mile 13.8) and Old Portage, OH, (river mile 40.25) (see Figure A1.1). As previously discussed, this area was identified in previous reports as the major source of sediment in the Cuyahoga River Basin.

The 303 square-mile study area was divided into seven subwatersheds for the sheet or diffuse nonpoint source erosion study. These seven subwatersheds are Mud Brook, Brandywine Creek, Tinkers Creek, Chippewa Creek, Furnace Run, Yellow Creek, and the local drainage of the Cuyahoga River. The subwatershed boundaries are shown on Plate A3-1 in Appendix I. The criteria for dividing the subwatersheds was that they had to be a minimum of 10,000 acres in size in order to use the existing sampling procedure for the Universal Soil Loss Equation (the equation used to estimate sheet erosion) and the subwatersheds had to start at the USGS suspended sediment gaging station. The USGS data would therefore provide a control point for sediment production for each of the subwatersheds. (Note: Because of the uncertainty of the data collected on the tributaries, see Exhibit E-2 in Appendix E; this data was subsequently not used for this purpose.)

Studies for five of the seven subwatersheds have been completed and interpretations have been made from the data collected for this Preliminary Feasibility Report. The field work and interpretations for the remaining two subwatersheds of Brandywine Creek and Yellow Creek will be completed during the Fall of 1979 and the results will be presented in the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

The results of the studies for the five completed subwatersheds cannot be expanded or interpreted for the remaining two subwatersheds or the CRRS study area as a whole. The sampling procedure (as outlined in the following sections) was not designed to eliminate any of the seven subwatersheds or to allow extrapolation of data from one subwatershed to another. It was designed to allow each of the subwatersheds to be evaluated as a self-contained unit. Basin-wide or study area general assumptions can be made only after all seven subwatersheds have been inventoried and the data base has been evaluated.

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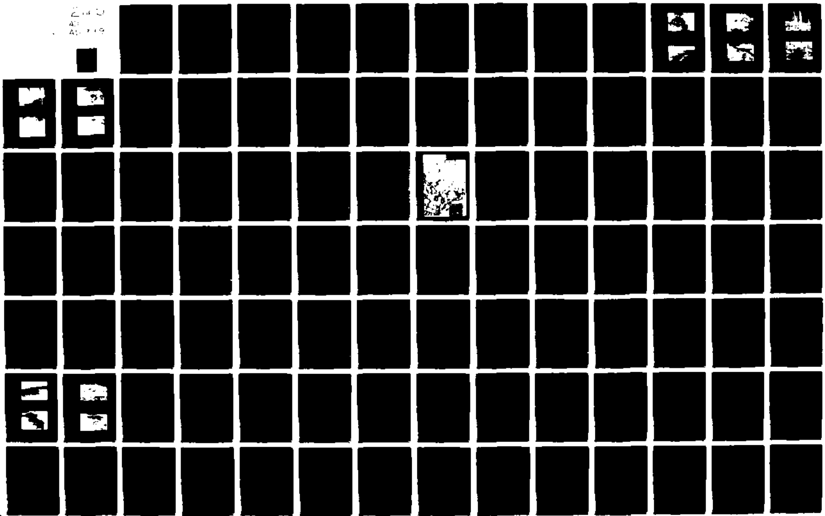


b. DESCRIPTION OF STUDY AREA - The following paragraphs present a brief narrative of the conditions observed while collecting and recording the field data required to estimate sheet erosion from diffuse nonpoint sources for the five completed subwatersheds. In addition, a brief discussion will be included on the land uses present in each of the subwatersheds. As will be discussed in subsection c (Methodologies and Approaches Used to Identify Erosion Problem Areas) land use was a variable that was recorded for each field site. The twelve land uses that were recorded are as follows:

Commercial/Industrial Land. Land that is primarily used for buying, selling, and processing goods and services, including sites for stores, factories, shopping centers, and industrial parks, together with necessary adjacent facilities such as underground and surface utilities, access streets and alleys, and other servicing structures, appurtenances, and measures.

Community Services Land. Land that is primarily used for schools, hospitals, churches, libraries, sewage, and water treatment plants, sanitary landfills, public parking areas, and other community service facilities, together with necessary adjacent facilities such as underground and surface utilities, access streets and alleys, and other servicing structures, appurtenances, and measures.

Cropland. Land that is primarily used for the production of adapted cultivated and close-growing crops for harvest, alone or in association with sod crops. Land in fruit and nut trees, grapes, etc., is included within the cropland land use.

Homestead. Land that is primarily used for dwellings, barns, pens, corrals, gardens, and other uses in connection with operating farms.

Hayland. Land that is primarily used for the production of hay from long-term stands of adapted forage plants.

Pastureland. Land that is primarily used for the production of adapted domesticated forage plants for livestock.

Recreation Land. Land or water that is primarily used for recreation. This land use occurs on picnic areas and play areas in the Cleveland and Akron Metropolitan Parks and the Cuyahoga Valley National Recreation Area, on county, township, and city parks, Boy Scout and Girl Scout camps, church camps, private camps, ski areas, and golf courses.

Residential Land. Land that is primarily used for permanent dwellings such as houses, apartments, and housing developments, including adjacent facilities such as underground and surface utilities, access driveways and alleys, and other servicing structures, appurtenances, and measures.

Transportation Land. Land that is primarily used for highways, roads, mass transit, railroads, utility rights-of-way, airports, and other transportation facilities.

Wildlife Land. Areas in which the primary use of land or water is for fish and wildlife habitat. Wildlife lands are those areas of open shallow water, marshes, State or local designated wildlife preserves, and other areas with noncommercial woody or brushy vegetation with weedy and native grasses as its cover type. It should be noted that wildlife land occurs in undeveloped areas of the parks systems.

Woodland. Land that is primarily used to produce adapted wood crops and to provide tree cover for watershed protection, beautification, etc.(does not include farmstead and field windbreaks.) Woodland will have trees of commercial value growing and they can be of any age. It should be noted that woodland areas occur in undeveloped areas of the park systems.

Other Land. Land in which the primary use is for purposes not described above. This land use was used within the study area to include mined lands, land fills, soil spoil or storage areas, and areas being held for commercial and residential development. These areas being held for development can be identified by two or more of the following site development factors: utilities already present, successional brushy and/or weedy cover type, established development on one or more boundaries, visable survey lot lines, access road areas marked or cleared, and development advertising visable.

(1) Mud Brook Subwatershed - Mud Brook subwatershed, with a drainage area of 29.3 square-miles, has an undulating land surface with poor drainage conditions in the glaciated plateau. Based on field observations the major eroding areas occur on steep forested slopes and on other land such as gravel pits and land being held for development. Photos A3.1 and A3.2 illustrate these conditions.

The primary land uses that occur in the subwatershed are residential, other land, wildlife land, and woodland. Table A3.1 presents a tabulation of the percentage of each land use recorded in Mud Brook subwatershed. This table was developed from the subwatershed computer printout of the collected field data. The procedure used was to expand the data collected from the areas of the subwatershed actually inventoried to a subwatershed-wide figure using the established sampling rate for Mud Brook subwatershed of 20 percent. This procedure will be explained in subsection c.

Plate A3-2 in Appendix I is a land use map for Mud Brook subwatershed produced by the Ohio Department of Natural Resources from their Ohio Capability Analysis Program (OCAP). OCAP is a computerized information system of natural resource data such as land use, soil type, topography, water resources, etc. This natural resource data is recorded for 1.15 acres cells throughout the State of Ohio. The system also has the ability to analyze and map this information. As will be discussed in subsection c, this system was also used to locate areas of high potential sheet erosion.

There are three main differences between the land use information stored in the OCAP system and the land use system used for the diffuse nonpoint source erosion study. The OCAP system has 31 separate land use categories whereas the system used for the erosion study has 12 land use categories. The 31 OCAP land use categories therefore had to be merged to produce 12 categories.

Table A3.1 - Land Use in Mud Brook Subwatershed 1/

Land Use	Acreage Contained in Subwatershed	Percent Contained in Subwatershed
1. Commercial/Industrial Land	750	4
2. Community Services Land	188	1
3. Cropland	562	3
4. Homestead	0	0
5. Hayland	376	2
6. Pastureland	750	4
7. Recreation Land	1,121	6
8. Residential Land	4,875	26
9. Transportation Land	1,125	6
10. Wildlife Land	3,000	16
11. Woodland	2,255	12
12. Other Land	3,750	20
	18,752	100 Percent

1/ Projection of land use acreage based on SCS sampling procedure.

The OCAP land uses for each 1.15 acre cell were determined from aerial photo interpretation whereas the system used for the erosion study used onsite field interpretation. (The OCAP land use information for the five county area of Summit, Portage, Geauga, Medina, and Cuyahoga Counties was provided by the Northeast Ohio Areawide Coordinating Agency (NOACA)). The photo interpretation process could not differentiate between cropland, homestead, hayland, and pastureland in all instances. For example, wheat fields were identified in the OCAP system as either pastureland or grassland whereas in the land use system used for the erosion study it was classified as cropland. Therefore, the OCAP land uses of grassland, cropland, and pastureland should be combined when comparing them to the land use categories of cropland, homestead, hayland, and pastureland for the erosion study.

The third difference between the OCAP land use system and the land use system used in the erosion study is in the definitions of woodland, wildlife, recreation, and other land use categories. The OCAP system does not differentiate between woodland and wildlife land and defines them as the same land use (woodland). Recreation land in the OCAP system includes both developed and undeveloped land within the various parks systems in the Cuyahoga River Basin. The land use system used in the erosion study classified the undeveloped land within the parks according to vegetation type (either woodland or wildlife land). Other land in the OCAP system does not include land being held for development since this could not be interpreted from aerial photos. OCAP classified this land as either woodland or grassland.

In addition to the three main differences in the land use systems, the OCAP subwatershed boundaries are slightly different than the subwatershed boundaries used in the erosion study. The main difference is that OCAP started their subwatershed boundaries at the Cuyahoga River whereas the erosion study began the boundary at the USGS sediment gaging station. The only problem this presented was in the Tinkers Creek subwatershed since the sediment gaging station is located approximately 6.5 miles upstream of the Cuyahoga River. It was possible, however, to manipulate the OCAP system to maintain the boundary at the sediment gaging station. In spite of these differences, the OCAP system provided a valuable tool for predicting where critical sheet erosion could occur in the study area, as discussed in subsection c.

(2) Tinkers Creek Subwatershed - Tinkers Creek subwatershed, with a drainage area of 85.6 square miles, has two-thirds of its area as rolling, hilly topography with a well defined drainage system. The other third of its area is a poorly drained marsh. Field observations indicated that the major areas of erosion occur on steep forested slopes and on other land such as gravel pits and land being held for development. Photos A3.3 and A3.4 illustrate these conditions.

The primary land uses that occur in the subwatershed are wildlife land, residential, and woodland as shown on Table A3.2. This subwatershed also had the highest percentage of community services land of any of the five subwatersheds studied for this report. Plates A3-3 and A3-4 in Appendix I are the OCAP land use maps for Tinkers Creek subwatershed.

Table A3.2 - Land Use in Tinkers Creek Subwatershed 1/

Land Use	Acreage Contained in Subwatershed	Percent Contained in Subwatershed
1. Commercial/Industrial Land	4,011	7
2. Community Services Land	3,287	6
3. Cropland	1,644	3
4. Homestead	548	1
5. Hayland	2,191	4
6. Pastureland	2,739	5
7. Recreation Land	2,191	4
8. Residential Land	10,409	19
9. Transportation Land	3,287	6
10. Wildlife Land	13,696	25
11. Woodland	6,026	11
12. Other Land	4,755	9
	54,784	100 Percent

1/ Projection of land use acreage based on SCS sampling procedure.

(3) Chippewa Creek Subwatershed - Chippewa Creek subwatershed, with a drainage area of 17.7 square-miles, has rolling steep topography with well defined drainage patterns in the glaciated plateau. Field observations indicated that the major areas of erosion occur on the steep forested slopes and on recreation land, particularly in the Brecksville Reservation. Photos A3.5 and A3.6 illustrate these conditions.

The primary land uses that occur in the subwatershed are residential, woodland, wildlife, recreation, and community services as shown on Table A3.3. Chippewa Creek subwatershed has the highest percentage of residential and community services land of any of the five subwatersheds studied. This is due to its proximity to the city of Cleveland, OH. Plate A3-5 in Appendix I is the OCAP land use map for this subwatershed.

(4) Furnace Run Subwatershed - Furnace Run subwatershed, with a drainage area of 17.7 square-miles, has a very steep sloped, forested land surface with high gradient and well-defined drainage channels that extend almost to the subwatershed boundary. Field observations indicated that extensive erosion is occurring in the steep sloped forested area. Erosion is accelerated because of the absence of any cover on the forest floor. Photos A3.7 and A3.8 illiustrate this condition.

The primary land uses that occur in Furnace Run subwatershed are woodland and wildlife. As shown on Table A3.4 they occur on 60 percent of the total area. Since it appears that these land uses have significant erosion problems it presents a potentially serious situation. Plate A3-6 in Appendix I is the OCAP land use map for this subwatershed. It should be noted that Furnace Run has about 26 percent of its area within the Cuyahoga Valley National Recreation Area and the Akron and Cleveland Metropolitan Parks System which the OCAP land use system classifies as recreation land. The erosion study land use system classified a majority of this land as either wildlife land or woodland because it was undeveloped.

(5) Local Drainage Subwatershed - Local drainage subwatershed, with a drainage area of 94.7 square miles, has broad, level flood plains with adjacent steep valley slopes. Field observations indicated that extensive erosion is occurring in the steep sloped forested area. Gully erosion was also identified as a significant source of sediment. Photos A3.9 and A3.10 illustrate these conditions.

The primary land uses that occur in the subwatershed are woodland, wildlife and residential land as shown on Table A3.5. As was the case in the Furnace Run subwatershed, wildlife land and woodland appear to have significant erosion problems and since these land uses occur on 56 percent of the area, a potentially serious situation exists. Plates A3-7 and A3-8 in Appendix I are the OCAP land use maps for this subwatershed. Again the OCAP system classified all the land in the Cuyahoga Valley National Recreation Area as recreational land whereas the erosion study system classified the undeveloped portion of this land as either wildlife land or woodland.

Table A3.3 - Land Use in Chippewa Creek Subwatershed 1/

Land Use	Acreage Contained in Subwatershed	Percent Contained in Subwatershed
1. Commercial/Industrial Land	268	2
2. Community Services Land	1,115	10
3. Cropland	0	0
4. Homestead	0	0
5. Hayland	0	0
6. Pastureland	134	1
7. Recreation Land	1,160	10
8. Residential Land	4,281	38
9. Transportation Land	624	6
10. Wildlife Land	1,115	10
11. Woodland	1,962	17
12. Other Land	669	6
	11,328	100 Percent

1/ Projection of land use acreage based on SCS sampling procedure.

Table A3.4 - Land Use in Furnace Run Subwatershed [1]

Land Use	Acreage Contained in Subwatershed	Percent Contained in Subwatershed
1. Commercial/Industrial Land	340	3
2. Community Services Land	113	1
3. Cropland	340	3
4. Homestead	113	1
5. Hayland	567	5
6. Pastureland	340	3
7. Recreation Land	567	5
8. Residential Land	1,360	12
9. Transportation Land	680	6
10. Wildlife Land	2,945	26
11. Woodland	3,850	34
12. Other Land	113	1
	11,328	100 Percent

[1] Projection of land use acreage based on SCS sampling procedures.

Table A3.5 - Land Use in Local Drainage Subwatershed 1/

Land Use	Acreage Contained in Subwatershed	Percent Contained in Subwatershed
1. Commercial/Industrial Land	2,824	5
2. Community Services Land	455	1
3. Cropland	2,277	4
4. Homestead	0	0
5. Hayland	547	1
6. Pastureland	2,004	3
7. Recreation Land	1,184	2
8. Residential Land	10,841	18
9. Transportation Land	2,460	4
10. Wildlife Land	13,301	22
11. Woodland	20,953	34
12. Other Land	3,826	6
	60,672	100 Percent

1/ Projection of land use acreage based on SCS sampling procedure.

Photo A3.1 - Erosion on steep forested slopes in Mud Brook subwatershed (SCS 4/78.)

Photo A3.2 - Unprotected gravel pit in Mud Brook subwatershed (SCS 7/77.)

Photo A3.3 - Erosion on steep forested slopes in Tinkers Creek subwatershed (SCS 5/78.)

Photo A3.4 - Erosion on land being held for residential development. Note absence of vegetation cover (SCS 12/77.)

Photo A3.5 - Erosion on steep forested slopes in Chippewa Creek subwatershed. Note exposure of tree root system (SCS 3/78.)

Photo A3.6 - Erosion in the Brecksville Reservation. Note absence of vegetation ground cover (SCS 9/79.)

Photo A3.7 - Erosion on steep forested slopes in Furnace Run subwatershed. Note absence of cover on forest floor.

Photo A3.8 - Erosion on steep forested slopes in Furnace Run subwatershed. Note lack of cover on forest floor.

Photo A3.9 - Erosion on steep forested slopes in local drainage subwatershed (SCS 3/79.)

Photo A3.10 - Gully erosion in local drainage subwatershed (SCS 3/79.)

c. METHODOLOGIES AND APPROACHES USED TO IDENTIFY EROSION PROBLEM AREAS - The determination of the quantity of gross erosion and the resultant critical erosion areas has been divided into two different study programs and evaluation procedures for this report. The first study program, and the most extensive in that it covers the entire study area of 303 square-miles, uses the Environmental Assessment Computer Program developed by the Soil Conservation Service. This program uses the Universal Soil Loss Equation (USLE) to determine the quantity of sheet and rill erosion from the land surface area (diffuse nonpoint sources). The second study program will evaluate the erosion occurring from identifiable nonpoint sources. This program will evaluate gully-type erosion on disturbed areas using the direct volume method. A discussion of the methodologies and data required to evaluate the diffuse nonpoint sources and identifiable nonpoint sources of erosion are presented in the following paragraphs.

(1) Diffuse Nonpoint Sources of Erosion

(a) General - The Environmental Assessment Computer Program was developed by the Soil Conservation Service, Midwest Technical Service Center, to evaluate impacts of proposed projects in watersheds. Items that are assessed include existing land use, crop production, sheet and rill erosion, wildlife habitat, and woodland production. Although this study was concerned only with the sheet and rill erosion component of this program, the factors required to assess the other components were also collected for future use. As will be discussed in the following sections these other factors were required to predict where sheet and rill erosion is occurring in noninventoried areas of the subwatersheds.

(b) Universal Soil Loss Equation - The Universal Soil Loss Equation (USLE) is the basic tool used in the Environmental Assessment Computer Program to calculate the quantity of sediment produced from sheet and rill erosion. The USLE is an empirical formula, developed by the Agricultural Research Service - U. S. Department of Agriculture, that groups the numerous interrelated physical and management parameters that influence the rate of erosion into six major factors that can be expressed numerically. The equation is $A = RKLSCP$ where:

A = the predicted long-term average annual soil loss expressed in tons per acre per year.

R = the rainfall factor. This factor measures the erosive force of the rainfall in an average year. Based on rainfall records for the area, this factor is 125 for the Cuyahoga River Basin.

K = the soil erodibility factor. This factor measures the ability of the soil particles to resist erosion and is a function of the properties of each individual soil type. Based on research, the K factors for the soil types encountered in the study area are shown on Table A3.6. As indicated, this factor ranged from 0.17 to 0.49.

L = the slope length factor. The length of slope as measured from the point of origin of overland flow during a rainfall event to either: (1) the point where the slope decreases to the extent that deposition begins; or (2) the point where runoff enters a defined channel. As the length of the slope increases the total quantity of sediment carried by the runoff increases which in turn increases the abrasiveness and thus the erosive potential of the flow. This factor is usually evaluated in combination with the slope-gradient factor (S) discussed below.

S = the slope gradient factor. The percent of slope or fall in 100 feet as measured in the field. As the slope increases the flow velocity of the runoff increases which in turn increases the erosive force of the flow. The slope length factor (L) and the slope gradient factor (S) are usually expressed as one factor (LS) when calculating the Universal Soil Loss Equation. Values for this LS factor are shown on Figure A3.1. Values for slopes of 20 percent or less and with lengths of slope of 800 feet or less were obtained from field research. Values for slopes greater than 20 percent or lengths of slope greater than 800 feet were projected from the existing data for slopes less than 20 percent.

C = the cover factor. The cover factor is a measure of the ability of the existing ground cover to absorb the erosive energy of either runoff or rainfall before it comes in contact with the soil particles. Cover factors for cropland are shown on Table A3.7. These values were determined from field research. Cover values for all other land uses are shown on Tables A3.8 and A3.9. These values are empirical and are the result of a concensus of opinion of interdisciplinary technical personnel from the SCS and Agricultural Research Service.

P = erosion control practice factor. The erosion control practice factor measures the effectiveness of erosion control practices such as terraces, contour cropping, strip cropping, etc. This factor did not apply to the Cuyahoga River Basin and was therefore assigned a value of 1 when the USLE was calculated.

Further information on the use and development of the Universal Soil Loss Equation is available in "Agricultural Handbook Number 537 - Predicting Rainfall Erosion Losses," dated 12/78.

The USLE is an effective tool in estimating the quantity of soil detached or dislodged from the land surface by raindrop action and the resultant runoff. It will predict the quantity of annual soil movement from the area of dislodgement. The distance the soil particle travels and where it is next deposited is not measured in the USLE system. It does not measure or calculate the delivery of the eroded soil particle to a stream system.

There is limited literature available in the field of sedimentation on the methods for determining sediment delivery rates. Estimates of sediment delivery and the rationale for developing sediment yields were reviewed in a

Table A3.6 - Soils Index 1/

Soil Name	Slope (Percent)	Symbol	K-Value 2/	T-Value 3/
Bogart loam	0-2	BgA	.32	5
Bogart loam	2-6	BgB	.32	5
Brecksville silt loam	25-70	BrF	.43	4
Berks silt loam	25-70	BeF	.28	3
Borrow-pits		Bp	.49	1*
Bogart Urban Land Complex		BuB	.32	1*
Bogart-Haskins loam	2-6	BhB	.32	5
Canadice silty clay loam	0-2	Ca	.49	3
Canadea silt loam	0-2	CcA	.43	3
Canadea silt loam	2-6	CcB	.43	3
Canfield silt loam	0-2	CdA	.37	4
Canfield silt loam	2-6	CdB	.37	4
Canfield silt loam	6-12	CdC2	.37	2
Cut & fill		CF	.24	1*
Canfield Urban Land Complex		CfB	.32	1*
Canfield Urban Land Complex		CfC	.32	1*
Carlisle Muck		Cg	-	-
Chagrin silt loam	0-2	Ch	.32	5
Chagrin silt loam, alkaline	0-2	Ck	.32	5
Chili loam	0-2	CnA	.32	4
Chili loam	2-6	CnB	.32	4
Chili loam	6-12	CnC	.32	4
Chili loam	25-18	CnD	.32	4

Table A3.6 - Soils Index 1/ (Cont'd)

Soil Name	Slope (Percent)	Symbol	K-Value 2/	T-Value 3/
Chili gravelly loam	6-12	CoC2	.32	3
Chili gravelly loam	12-18	CoD2	.32	3
Chili gravelly loam	18-25	CoE2	.32	3
Chili silt loam	0-2	CpA	.32	4
Chili silt loam	2-6	CpB	.32	4
Chili silt loam	6-12	CpC	.32	4
Chili Urban Land Complex		CuB	.24	1*
Chili-Wooster Complex	18-25	CwE2	.24	3
Condit silty clay loam	0-2	Ct	.37	4
Conotton-Oshtemo Complex	18-25	CyE	.24	3
Conotton-Oshtemo Complex	25-50	CyF	.24	3
Damascus loam	0-2	Da	.32	5
Dekalb sandy loam	6-12	DkC	.24	3
Dekalb sandy loam	12-18	DkD	.24	3
Dekalb sandy loam	18-25	Dke	.24	3
Dekalb sandy loam	25-70	DkF	.24	3
Ellsworth silt loam	2-6	ELB	.43	3
Ellsworth silt loam	6-12	ELC	.43	3
Ellsworth silt loam	6-12	ELC2	.43	3
Ellsworth silt loam	12-18	ELD	.43	3
Ellsworth silt loam	12-18	ELD2	.43	3
Ellsworth silt loam	18-25	ELE	.43	3
Ellsworth silt loam	18-25	ELE2	.43	2
Ellsworth silt loam	25-70	ELF	.43	3
Ellsworth silt loam	25-50	ELF2	.43	2
Ellsworth silt loam	6-12	EsC	.43	3
Ellsworth Urban Land Complex		EuB	.32	1*
Ellsworth Urban Land Complex		EuC	.32	1*

Table A3.6 - Soils Index 1/ (Cont'd)

Soil Name	Slope (Percent)	Symbol	K-Value 2/	T-Value 3/
Fitchville silt loam	0-2	FcA	.37	5
Fitchville silt loam	2-6	FcB	.37	5
Euclid silt loam	0-2	FdA	.37	5
Fitchville Urban Land Complex		Fn	.49	1*
Fitchville silt loam	0-2	FlA	.37	5
Geeburg silt loam	2-6	GbB	.43	3
Geeburg silt loam	6-12	GbC2	.43	2
Geeburg silt loam	12-18	GbD2	.43	2
Geeburg-Mentor silt loam	25-70	GeF	.43	2
Glenford silt loam	2-6	GfB	.37	5
Glenford silt loam	6-12	GfC2	.37	4
Glenford silt loam	12-18	GfD2	.37	4
Gravel Pits		GP	.17	1*
Haskins-Canadea Complex	2-6	HcB	.37	4
Holly silt loam	0-2	Ho	.28	5
Hornell silt loam	2-6	HrB	.43	3
Hornell silt loam	6-12	HrC	.43	3
Hornell silt loam, alkaline	12-18	HrD	.43	3
Jimtown loam	0-2	JtA	.32	4
Jimtown loam	2-6	JtB	.32	4
Jimtown Urban Land Complex		Ju	.32	1*
Lobdell silt loam	0-2	Le	.37	5
Lorain silty clay loam	0-2	Ln	.32	5

Table A3.6 - Soils Index 1/ (Cont'd)

Soil Name	Slope (Percent)	Symbol	K-Value 2/	T-Value 3/
Loudonville silt loam	2-6	LoB	.32	4
Loudonville silt loam	6-12	LoC	.32	4
Loudonville silt loam	6-12	LoC2	.32	3
Loudonville silt loam	12-18	LoD	.32	3
Loudonville silt loam	18-25	LoE	.32	3
Loudonville Urban Land Complex		LuC	.28	1*
Luray silt loam	0-2	Ly	.32	5
Made land, sanitary fill		Md	.49	1*
Mahoning silt loam	0-2	MgA	.43	3
Mahoning silt loam	2-6	MgB	.43	3
Mahoning silt loam	2-6	MLB	.43	3
Mahoning Urban Land Complex		Mn	.28	1*
Mahoning Urban Land Complex		Mm	.28	1*
Mitiwanga Urban Land Complex		Mx	.28	1*
Mitiwanga silt loam	0-2	MtA	.32	4
Mitiwanga silt loam	2-6	MtB	.32	4
Orrville silt loam	0-2	Or	.31	5
Oshtemo sandy loam	0-2	OsA	.24	5
Oshtemo sandy loam	2-6	OsB	.24	5
Oshtemo sandy loam	6-12	OsC	.24	5
Oshtemo sandy loam	25-70	OsF	.24	3
Olmsted loam	0-2	Od	.24	5
Ravenna silt loam	0-2	ReA	.37	3
Ravenna silt loam	2-6	ReB	.37	3
Rittman silt loam	2-6	RsB	.43	4
Rittman silt loam	2-6	RsB2	.43	3

Table A3.6 - Soils Index 1/ (Cont'd)

Soil Name	Slope (Percent)	Symbol	K-Value 2/	T-Value 3/
Rittman silt loam	6-12	RsC	.43	3
Rittman silt loam	6-12	RsC2	.43	3
Rittman silt loam	12-18	RsD	.43	4
Rittman silt loam	12-18	RsD2	.43	3
Rittman silt loam	18-25	RsE2	.43	3
Rittman silt loam	2-6	RtB	.43	4
Rittman silt loam	6-12	RtC	.43	4
Rittman Urban Land Complex		RuB	.28	1*
Rittman Urban Land Complex		RuC	.28	1*
Rough Broken Land, clay and silt		Rv	.43	2*
Rough Broken Land, silt and sand		Rw	.37	4*
Sebring silt loam	0-2	Sb	.37	5
Shale rock land		Sc	.28	1*
Tioga loam	0-2	Tg	.20	5
Trumbull silty clay loam	0-2	Tr	.37	3
Urban land		Ur	.32	1*
Wadsworth Urban Land		Wb	.43	1*
Wadsworth silt loam	0-2	WaA	.43	4
Wadsworth silt loam	2-6	WaB	.43	4
Wheeling silt loam	0-2	WrA	.32	4
Wheeling silt loam	2-6	WrB	.32	4
Willette muck		Wt	-	-

Table A3.6 - Soils Index 1/ (Cont'd)

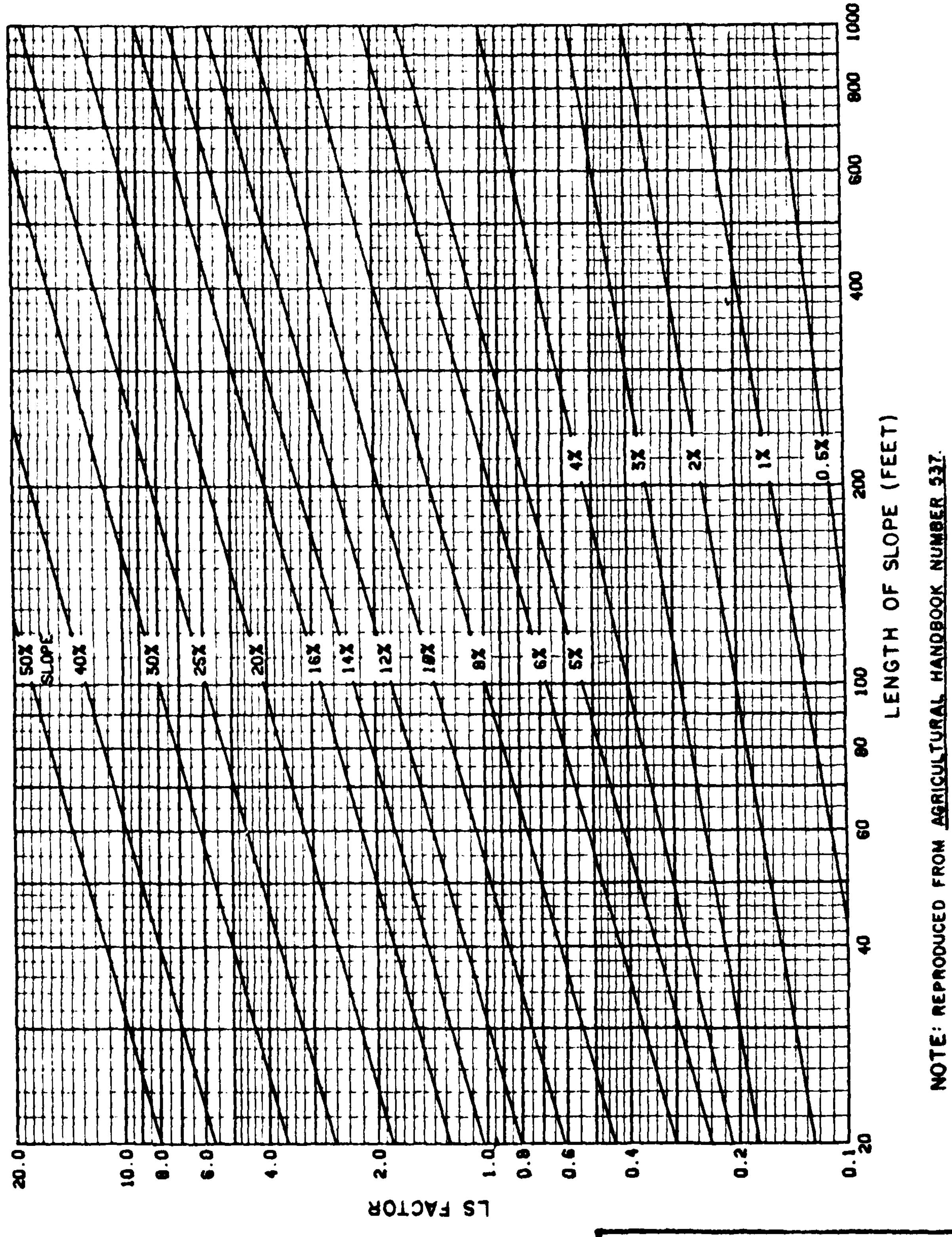
Soil Name	Slope	Symbol	K-Value 2/	T-Value 3/
	(Percent)			
Wooster silt loam	2-6	WuB	.37	4
Wooster silt loam	2-6	WuB2	.37	3
Wooster silt loam	6-12	WuC	.37	4
Wooster silt loam	6-12	WuC2	.37	3
Water		W	-	-

* Assigned values - not in Technical Guide

1/ Information obtained from published soil surveys made by the SCS and ODNR, Division of Lands and Soil.

2/ Soil erodibility factor used in the Universal Soil Loss Equation to predict sheet and rill erosion.

3/ Tolerable soil loss value (the maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely).



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

SLOPE EFFECT CHART

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE A3.1

Table A3.7 - "C" Factors for Cropland 1/

Cropping 2/ System	"C" Factor Spring Plow (Residue Left)	Fall Plow (Residue Left)	Spring Plow (Residue Removed) 3/	Fall Plow (Residue Removed) 3/
Cont. Sb	.41	.45	.54	.57
CSbSb	.39	.44	.53	.56
CSb	.38	.43	.52	.55
CCSb	.37	.42	.51	.54
Cont. C	.36	.40	.49	.53
CCSbOx	.27	.31	.33	.38
CCSbWx	.26	.30	.31	.37
CCCOx	.26	.30	.32	.37
CCCWx	.26	.29	.30	.37
CSbOx	.24	.27	.27	.33
CSbWx	.23	.27	.26	.32
CCOx	.22	.26	.26	.32
CCWx	.22	.25	.25	.31
COx	.20	.24	.25	.30
CWx	.20	.24	.23	.29
CCCM	.19	.22	.27	.29
CCSbOM	.17	.20	.23	.24
CCSbWM	.17	.20	.22	.24
CCCOM	.16	.19	.23	.24
CCCWM	.16	.19	.21	.24
CSbOM	.15	.17	.18	.20
CSBWM	.14	.17	.17	.19
CCM	.14	.16	.20	.21
CCCMMM	.13	.15	.18	.19
CSbOMM	.12	.14	.15	.16
CSbWMM	.11	.14	.14	.16
CxSbOMM	.11	.14	.15	.16
CxSbWMM	.11	.14	.13	.16
CCOM	.12	.14	.16	.16
CCWM	.11	.13	.14	.15

Table A3.7 - "C" Factors for Cropland 1/ (Cont'd)

Cropping 2/ System	"C" Factor Spring Plow (Residue Left)	Fall Plow (Residue Left)	Spring Plow (Residue Removed) 3/	Fall Plow (Residue Removed) 3/
CxCOM	.11	.13	.15	.16
CxCWM	.11	.13	.14	.15
CCMM	.10	.12	.15	.16
CSbCMMM	.10	.12	.13	.14
CSbWMMM	.096	.11	.11	.13
CCOMM	.093	.112	.12	.13
CCWMM	.093	.108	.12	.12
CXCOMM	.093	.111	.13	.13
CXCWMM	.092	.108	.12	.12
CCOMMM	.078	.074	.11	.11
CCWMMM	.078	.091	.10	.10
CxCOMMM	.078	.094	.107	.11
CxCWMMM	.078	.091	.096	.10
CM	.071	.080	.09	.10
COWMM	.056	.060	.066	.068
COM	.055	.072	.066	.077
CWM	.055	.065	.061	.070
COMM	.043	.055	.051	.059
CWMM	.042	.051	.047	.054
CWMMM	.035	.041	.038	.044
CWMMMM	.029	.035	.033	.038

1/ Information obtained from "SCS Technical Guide," Columbus, OH, Revised 12/77.
2/ C = Corn
Sb = Soybeans
M = Meadow
O = Spring grain
W = Winter Grain
x = Cover or green manure crop
3/ Residue removed includes corn stover and straw.

Table A3.8 - "C" Values for Land Uses of Commercial/Industrial, Community Services, Homestead, Hayland, Pastureland, Recreation, Residential, Transportation, Other Land, Woodland and Wildlife Land. 1/ 2/ 3/

Vegetal Canopy: Type and Height of Raised Canopy 4/	Canopy Cover 5/ %	Type of 6/ Ground Cover	"C" Factor: Percent Ground Cover in Contact With the Ground Surface: 0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ Information obtained from "Agricultural Handbook Number 537."

2/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

3/ For land uses of woodland and wildlife land with slopes of 0 to 6 percent use, Table A3.9.

4/ Average fall height of waterdrops from canopy to soil surface: m = meters.

5/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

6/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (such as weeds) with little lateral-root network near the surface, and/or undecayed residue.

Table A3.9 - "C" Factors for Woodland and Wildlife Land on Slopes of 0 to 6 Percent 1/

Stand Condition	Tree Canopy 2/ (% of Area)	Forest 3/ Litter (% of Area)	Underground 4/	"C" Factor
Well Stocked	100-75	100-90	Managed 5/	.0001 - .001
			Unmanaged 5/	.003 - .011
Medium Stocked	70-40	85-75	Managed	.002 - .004
			Unmanaged	.01 - .04
Poorly Stocked	35-20	70-40	Managed	.003 - .009
			Unmanaged	.02 - .09 6/

1/ Information obtained from "Agricultural Handbook Number 537."

2/ When tree canopy is less than 20 percent, the area will be considered as grassland or cropland for estimating soil loss (see Table A3.8).

3/ Forest litter is assumed to be at least two inches deep over the percent ground surface area covered. If not, use Table A3.8.

4/ Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

5/ Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

6/ For unmanaged woodland with litter cover of less than 75 percent, C values should be derived by taking 0.7 of the appropriate values in Table A3.8. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

paper by Graham W. Renfro, SCS, at a Sediment Yield Workshop, on 28 November 1972. He states that, "Sediment estimates should be tempered with judgment and consideration of other influencing factors such as texture, relief, type of erosion, the sediment transport system, and area deposition within the drainage area." Considering the foregoing influencing factors and SCS field observations within the CRRS area, delivery rates were decided upon for each land use. These rates are presented in Table A3.10.

It is important to remember the difference between soil particle dislodgement and sediment delivery. As stated before, soil erosion is the dislodgement or detachment of a soil particle from the soil structure. Sediment delivery refers to the transport and deposition of that detached soil particle. For the purpose of this study, sediment delivery will mean those detached soil particles that are transported to a stream channel. Once the delivered sediment reaches a defined channel it has the potential of being transported all the way to the navigation channel at Cleveland Harbor.

(b) Sampling Procedure Used to Estimate Erosion From Diffuse Nonpoint Sources - The Environmental Assessment Computer Program was applied to a representative sample of the land area in each subwatershed and, based on the established individual sampling rates, the results were expanded for the entire subwatershed. The sampling method for the diffuse nonpoint source erosion inventory was determined by Dr. Jeffrey Goebel of the Statistical Laboratory, Iowa State University, Ames, Iowa. In this procedure, the entire 303 square-mile area was used in the computer selection of the Primary Sample Units (PSU's) for each subwatershed. The PSU's are randomly selected squares or land units with 2,000 feet to a side or an approximate area of 91.82 acres. A small portion of the PSU's occur at or near the subwatershed boundaries and in this case the PSU's were either cut off to conform with the boundary or extended to the subwatershed boundary. This resulted in some PSU's with irregular sides and an area either greater or less than 91.82 acres. The location of the PSU's are shown on Plate A3-9 in Appendix I.

Each subwatershed has its own sampling rate and can be treated as a statistically sound entity. The subwatersheds and their corresponding sampling rates are as follows:

Mud Brook	- 20 percent sample
Brandywine Creek	- 20 percent sample
Tinkers Creek	- 8 percent sample
Chippewa Creek	- 22 percent sample
Furnace Run	- 25 percent sample
Yellow Creek	- 20 percent sample
Local Drainage	- 10 percent sample

The average basin-wide sampling rate is 17.85 percent. (The sampling rates for Tinkers Creek and Local Drainage were reduced because the size of the subwatersheds (85.6 square miles and 94.7 square miles respectively) permitted a statically sound lower sampling rate.)

Once the PSU's were established for each subwatershed, a template, with a grid pattern of points, was spun on each PSU center point to locate the

Table A3.10 - Estimated Sediment Delivery Rate to Cuyahoga River for Dislodged Sediment

Land Use	Estimated Delivery Rate (Percent)
1. Commercial/Industrial Land	50
2. Community Services Land	30
3. Cropland	20
4. Homestead	10
5. Hayland	10
6. Pastureland	10
7. Recreation Land	70
8. Residential Land	30
9. Transportation Land	50
10. Wildlife Land	40
11. Woodland	70
12. Other Land	50

points to be evaluated in the field. This template procedure does not give the same acreage figure per point in all the subwatersheds. The exact acreage figure per point can be calculated by taking the Ames, Iowa Statistical Laboratory sampling rate times the USGS measured subwatershed area in acres and dividing by the total number of points sampled in each subwatershed. For example, in Mud Brook subwatershed the calculation is:

$$\frac{18{,}752 \text{ acres} \times 0.20 \text{ sample rate}}{415 \text{ points}} = 9.03 \text{ acres per point}$$

This acre per point figure was then used in expanding the data from the PSU's to a subwatershed wide data base figure. Table A3.11 presents the acres per point figure for each subwatershed.

Once the points to be evaluated for each PSU were established, the points were located in the field and the necessary data was collected as it occurred the day it was observed or measured on the landscape. Data collected for the USLE included soil type from published soil surveys (to determine the "K" factor), length of slope and percent of slope using a Sunnto PM-5 Clinometer Hypsometer (to determine the "LS" factor), and an estimate of the "C" factor from Tables A3.7 to A3.9. In addition to the data required for the USLE, additional data such as land use, cover type, woodland production information, and wildlife habitat parameters were collected for other portions of the Environmental Assessment Computer Program. The collected field data was then coded onto field work sheets which were then photocopied and sent to the SCS Midwest Technical Service Center, Automatic Data Processing, Lincoln, Nebraska, for computer processing. A copy of a completed field data sheet and photo map is displayed in Figure A3.2. An input data check first run was completed and corrections to input data were made. The final computer run was then made with various specified combinations of data requested.

(c) Identification of Critical Erosion Areas - The identification of the critical erosion problem areas was accomplished by locating areas of each subwatershed that had actual sheet and rill erosion (as determined by the USLE) greater than the tolerable soil loss value (T). The term tolerable soil loss is used to denote the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. This rate has usually been expressed in terms of average soil loss per acre per year. A special summary sheet was then prepared by subwatershed of these critical soil erosion areas by land uses. These tables appear in the next section.

The USLE will estimate the total volume of sheet and rill erosion occurring in the subwatersheds. It will not, however, locate the critical eroding areas on the landscape since only a percentage of the land surface is actually sampled. Results of the diffuse nonpoint erosion studies indicated that critical eroding areas for each subwatershed (areas with actual sheet and rill erosion greater than the tolerable soil loss factor) could be characterized by land use in combination with certain soil types. These combinations differed for each subwatershed. Since the Ohio Capability Analysis Program (OCAP) stores both soil type and land use data in its computer data bank, it was possible to locate potential critically eroding areas for areas

Table A3.11 - Subwatershed Sample Rate Data

Subwatershed	Area in Acres	Square Miles	No. of Primary Sample Units	Sample Rate (Percent)	No. of Sample Points	Corrected Acres per Pt.
Mud Brook	18,752	29.3	44	20	415	9
Brandywine Creek	17,408	27.2	41	20	1/	1/
Tinkers Creek	54,784	85.6	50	8	480	9.2
Chippewa Creek	11,328	17.7	28	22	256	9.7
Furnace Run	11,328	17.7	33	25	278	10.2
Yellow Creek	19,648	30.7	47	20	1/	1/
Local Drainage	60,672	94.8	71	10	666	9.11

1/ Brandywine and Yellow Creek subwatersheds were not sampled for this PFR.

15 Suggested format for an environmental assessment worksheet

Conservation Practices on the Land

1 Worksheet	2 Watershed Sample	3 Sample Point	4 Soil	5 Principal L.U.	6 Dryland or Irrigated	7 Type of Cover	8 Production	9 Plant Community: Condition / Trend / Forage Value	10 Woodland: Acc. Stock / Size	11 Use of Cover	12 Interspersion of Cover Types: Water / Grassy / Woody / Crop	13 Residue Height	14 Canopy %	Code No.	Code No.	Code No.	Code No.
A	633	1	Rw	13	1	12	0	000	13	4	5316	1	6				
A		2	Rw	13		12	0	000	22	4	5416	1	5				
A		3	CpB	13		12	0	000	22	4	4316	1	6				
A		4	Rw	14	1	14	0	000	00	5	4216	1	2				
A		5	WrA	10	1	17	0	000	00	4	4136	1	1				
A		6	WrA	09	1	08	0	000	00	5	4146	2	1				
A		7	Rw	13	1	12	0	000	11	4	3316	1	6				
A		8	Rw	13	1	12	0	000	13	4	4316	1	6				
A		9	WrA	09	1	08	0	000	00	5	3146	2	1				
A		10	Ck	09	1	08	0	000	00	5	3136	2	2				
A		11	Rw	13	1	12	0	000	12	4	3216	1	6				
A		12															
A		13															
A		14															
A		15															
A		16															
A		17															
A		18															
A		19															
A		20															
		21															

FIGURE A3.2-TYPICAL UPLAND SURVEY DATA SHEET

Form	Watershed Sample	Sample Point	Sheet & Rill Erosion: Length of Slope	% Slope	Cm or PC Factor "C"	Alternative Conservation Practices: Code No.	Code No.	Code No.	Code No.	Code No.	Code No.	Code No.	Remarks
B	633	1	100	55	041								
B		2	100	65	041		342-1ac		419-1				
B		3	200	02	011		342-3ac		419-3				Clear cut - Transmission Corridor
B		4	160	55	240								
B		5	100	01	013								
B		6	200	02	003								
B		7	50	80	041								
B		8	100	78	083		342-2ac		350-1	584-200'			
B		9	100	02	003		342-1ac		410-1				
B		10	300	02	003		342-1ac		410-1	584-500'		580-200'	
B		11	200	80	130		342-2ac		574-1	584-800'			
B		12											
B		13											
B		14											
B		15											
B		16											
B		17											
B		18											
B		19											
B		20											

FIGURE A3.2-7 TYPICAL UPLAND SURVEY DATA SHEET (cont'd)

CRRS Sample 633
Mud Brook
Summit Co., O.

FIGURE A3.2-TYPICAL UPLAND SURVEY DATA SHEET (cont'd)

not sampled. This was accomplished by having the computer locate and map the areas that had the specified combinations of land use and soil type for each subwatershed. Topographic overlay maps were then prepared for each subwatershed to allow identification of those potential critically eroding areas on the surface of the land. These maps will be presented in the next section.

It should be noted that the land use categories for OCAP and the Environmental Assessment Computer Program differ in several respects, as previously discussed. Therefore, in order to produce the potential critically eroding area maps for each subwatershed, some manipulation of the OCAP land use categories was required. These manipulations will be discussed in the next section for each subwatershed. In spite of these manipulations the OCAP system provided a valuable tool in locating potential critically eroding areas.

(d) Other Erosion Studies in the Study Area - There have been several other erosion potential studies conducted within the Cuyahoga River Restoration Study area. One of these is the OCAP system by ODNR using the published soil survey and parts (RKLS) of the USLE. This program produces a county map showing geographic location of land areas that are potentially sensitive to erosion if certain conditions were to be applied. The Northeast Ohio Areawide Coordinating Agency 208 Water Quality Plan also uses the OCAP maps as a system to identify potential erosion problem areas. The use of only one weighted or average factor for the various USLE factors gives an indication where the problem is and the relative importance of the problem in the above programs.

These types of broad or generalized analysis programs compliment the Cuyahoga River Restoration Study in that they look at the overall regional problems and generally identify potential broad resource problem areas. All the other studies were derived from soils maps, aerial photo interpretations and inputs from technical field personnel. The CRRS has, on the other hand, ground truth information as base line data in addition to the information sources of aerial photo interpretations, soils maps, and inputs from other studies.

(2) Identifiable Nonpoint Sources of Erosion - As previously indicated, a separate study program was used to identify and quantify the sediment produced by identifiable nonpoint sources (gully erosion on disturbed areas). For this study program, aerial photos from the years 1936-1937, 1951, 1969, 1974, and 1977 were extensively used to identify these identifiable nonpoint sources. This aerial photo interpretation process was supplemented with field observations made while collecting the field data required by the Environmental Assessment Computer Program. In addition, it was decided to hold identification of these source areas close to or within the Standard Project Flood area as defined in the "Flood Plain Information Report for the Cuyahoga River, Cuyahoga and Summit Counties, OH," (September 1969) by the Corps of Engineers, Buffalo District. The reason for this decision was that the sediment produced in these source areas, due to their proximity to the Cuyahoga River channel, is generally delivered directly to the river and causes an immediate impact on the river system.

The quantity of sediment produced by these identifiable nonpoint sources will be determined by the direct volume method. The equation for this method is A = LHRW where:

A is the tons of dislodged soil material per year
L is the length of the eroding segment
H is the height of the eroding segment
R is the annual lateral recession of the eroding segment
W is the unit weight of the eroding material

Due to time constraints, the quantity of sediment produced by these source areas was not determined for this Preliminary Feasibility Report. Quantities will be determined after each site is visited in the fall of 1979 and the field data required by the above factors is collected if the recommendation of this report is to continue into Stage 3 planning. The results would then be reported in the Final Feasibility Report.

It is important to remember the difference between sediment produced by diffuse nonpoint sources (sheet and rill erosion) and sediment produced by identifiable nonpoint sources (gully erosion in disturbed areas). Although the identifiable nonpoint sources are represented in the expanded erosion data for diffuse nonpoint sources, the USLE did not always evaluate these sources as severe erosion areas. That is, the estimated sheet erosion occurring in the area was below the tolerable soil loss value. The erosion that occurs here is gully erosion and must be measured by the direct volume method.

d. UPLAND COMPONENT EROSION PROBLEM AREAS - This section presents the results of the studies conducted to identify and quantify the sources of sediment from erosion of the land surface. As previously mentioned, sources of sediment have been divided into two areas: (1) sediment produced from diffuse nonpoint sources; and (2) sediment produced from identifiable nonpoint sources. The results of the studies for these two sources of erosion are discussed below.

(1) Diffuse Nonpoint Sources of Erosion - Diffuse nonpoint sources of sediment refer to the entire land surface where sheet and rill erosion occurs. For this study the 303 square-mile drainage basin between Independence (river mile 13.8) and Old Portage (river mile 40.25) was divided into seven subwatersheds (Mud Brook, Brandywine Creek, Tinkers Creek, Chippewa Creek, Furnace Run, Yellow Creek, and the local drainage of the Cuyahoga River). Studies for five of the seven subwatersheds are completed and the results are discussed below. Studies for the remaining two subwatersheds (Brandywine Creek and Yellow Creek) will be completed in the Fall of 1979 and the results will be reported in the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

The following discussion is grouped into six subsections: (a) Mud Brook; (b) Tinkers Creek; (c) Chippewa Creek; (d) Furnace Run; (e) Local drainage of the Cuyahoga River; and (f) Summary and General Conclusions. Each subsection will discuss the sheet and rill erosion occurring in the subwatershed under study as calculated by the Environmental Assessment Computer Program (EACP). This will be followed by a discussion on the OCAP maps produced to locate areas of potential critical erosion, including a discussion on the specific combinations of land use and soil types that were specified.

(a) Mud Brook Subwatershed - Table A3.12 presents: (1) a summary of the estimated volume of sediment produced from critical erosion areas in the Mud Brook subwatershed; and (2) the estimated volume of this sediment delivered to the Cuyahoga River system. This table was developed from the data generated by the Environmental Assessment Computer Program. It includes only those areas that have an existing rate of sheet erosion greater than the tolerable soil loss value. All other areas with sheet erosion rates less than the tolerable soil loss value contribute an insignificant volume of sediment and were therefore not included. The expansion procedure used to derive these quantities was documented earlier in this Appendix.

As indicated on Table A3.12, only 1,395 acres (or 7 percent of the total subwatershed area) presently has a critical erosion problem. These areas produce about 57,000 tons of sediment per year. This represents approximately 94 percent of the total volume of sediment produced from sheet and rill erosion in the entire subwatershed. Of this 57,000 tons of sediment, it is estimated that approximately 32,000 tons are delivered to the Cuyahoga River system annually.

The majority of the sediment produced from sheet and rill erosion (84 percent) occurs on the land uses of woodland and other land. Within these two land uses the soil types that are eroding are primarily composed of silt and fine sandy loams which are highly erodible. They also generally have

steep slopes ranging from 6 to 70 percent. In addition, they have a poor protective cover (weedy or bare) which leaves the soil surface exposed to the full erosive force of the raindrop and resultant runoff. The combined effect of these three factors is responsible for the high sediment yields from these two land uses.

Plates A3-10, A3-11, and A3-12 in Appendix I are the OCAP maps produced by ODNR which show the areas of potential critical erosion. Plate A3-10 locates the potential critical erosion areas on a USGS topographic map. Plates A3-11 and A3-12 show the soil type and land use for each eroding area, respectively. These maps were produced by having the OCAP computer scan its land use and soil type data base and map out those areas that had the critical combinations of land use and soil type shown in Table A3.13. These critical combinations were developed from the data presented in Table A3.12, modified to account for differences in land use catagories between the OCAP system and the Environmental Assessment Computer Program (EACP) system. In addition, cut and fill areas, gravel pits, and made land on other land use was requested in the OCAP system for all five subwatersheds. Studies in the subwatersheds where these combinations were actually sampled indicated that they always produced sheet erosion above the tolerable soil loss value and were therefore requested for all five subwatersheds.

The OCAP system identified a total potential critical erosion area of 2,303 acres, or 12.24 percent of the total area. These figures are slightly higher than the figures generated by the EACP system (1,395 acres or 7 percent of the total area). This difference is due to the differences in land use classifications between the two systems. For example, the EACP system identified woodland areas as a major source of sediment which is produced from sheet and rill erosion but indicated that sheet and rill erosion on wildlife land was not a significant problem. However, since the OCAP system classifies wildlife land as woodland, these wildlife areas were identified on the OCAP maps as areas of critical erosion. Therefore, the OCAP maps should be interpreted as potential areas of critical erosion only.

As shown on Plate A3-10, potential critical erosion sites are concentrated near tributary drainage channels and where steep valley slopes are present, particularly west of State Route 8. The areas where no potential critical erosion is indicated are primarily marshy-wetland areas or older residential areas where adequate ground cover has been established.

Table A3.12 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Mud Brook Subwatershed

Land Use		Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered to the River/Year
Other Land	CuB	Chili urban land complex	45	weeds	1	18.9	851		
	ELB	Ellsworth silt loam	45	bare	3	16.5	743		
	ELE2	Ellsworth silt loam	45	bare	2	3.2	144		
	EuC	Ellsworth urban land complex	45	weeds	1	24.2	1,089		
	Md	Made Land - sanitary fill	45	bare	1	3.5	158		
	Mn	Mahoning urban land complex	45	bare	1	1.5	68		
	RsC	Rittman silt loam	45	grass	3	8.5	383		
	RsD2	Rittman silt loam	45	woody & grassy	3	3.3	149		
	Rw	Rough broken land, silt and sand	45	woody & grassy	4	279.9	12,596		
			405				16,181	50	8,091 tons
Cropland	ELB	Ellsworth silt loam	45	corn	3	3.6	162		
	ELB	Ellsworth silt loam	90	corn	3	12.1	1,089		
	ELB	Ellsworth silt loam	45	wheat	3	9.3	419		
	RsE2	Rittman silt loam	90	wheat	3	71.0	6,390		
	Tr	Trumbull silty clay loam	45	wheat	3	5.8	261		
	CnB	Chili loam	45	corn	4	5.0	225		
	MgB	Mahoning silt loam	45	corn	3	5.7	257		
			405				8,803	20	1,761 tons

Table A3.12 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Mud Brook Subwatershed

Land Use	Soil Type	Expanded 1/ Acres for Subwatershed	Cover Type	Tolerable 2/ Soil Loss Value (T)	Actual 3/ Tons/ Acre/ Year	Total 4/ Critical Tons for WS/Year	Sediment 5/ Delivery Rate (Percent)	Quantity of Sediment Delivered to the River/Year
Woodland	ELE2 Ellsworth silt loam	45	woody, comm.	2	2.8	126		
	ELF2 Ellsworth silt loam	45	woody, comm.	2	9.0	405		
	Rw Rough broken land, silt and sand	45	woody, comm.	4	46.7	2,102		
	Rw Rough broken land, silt and sand	405	woody, noncomm.	4	72.6	29,403		
		540				32,036	70	22,425 tons
Wildlife Land	ELE2 Ellsworth silt loam	45	woody & grassy	2	6.6	297		
		45				297	40	119 tons
Totals for Mud Brook Subwatershed		1,395 acres (or 7 percent of the subwatershed area) presently has a critical erosion problem. 6/				57,317 tons dislodged/year or 94 percent of the total tons dislodged from the total subwatershed area		32,396 tons delivered/year

1/ Nine acres per sample point (from Table A3.11) divided by Mud Brook sampling rate of 20 percent and multiplied by number of data points encountered in the sample data which had the same land use, soil type, and cover type, with erosion above T.

2/ The maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely.

3/ Existing rate of sheet and rill erosion as determined by the Universal Soil Loss Equation.

4/ Expanded acres for subwatershed multiplied by rate of sheet and rill erosion

5/ Estimated delivery rate of sediment produced from sheet and rill erosion to tributary stream (from Table A3.10).

6/ See Plate A3-10 in Appendix I for the location of critically eroding areas in the Mud Brook Subwatershed.

Table A3.13 - Critical Combinations of Land Use and Soil Type That Produce Erosion Above the Tolerable Soil Loss Value - Mud Brook Subwatershed 1/

Land Use	Soil Type	
1. Woodland/Wildlife/Other Land	CF 2/	Cut & Fill
	CuB	Chili urban land complex
	ELB	Ellsworth silt loam
	ELE2	Ellsworth silt loam
	ELF2	Ellsworth silt loam
	EuC	Ellsworth urban land complex
	GP 2/	Gravel Pit
	Md	Made Land
	Mn	Mahoning urban land complex
	RsC	Rittman silt loam
	RsD2	Rittman silt loam
	Rw	Rough broken land, silt, and sand
2. Cropland/Pastureland/ Grassland	ELB	Ellsworth silt loam
	RsE2	Rittman silt loam
	Tr	Trumbull silty clay loam
	CnB	Chili loam
	MgB	Mahoning silt loam

1/ Critical combinations used in OCAP system to produce Plates A3-10 to A3-12 in Appendix I.

2/ Soil types added based on results of studies in other subwatersheds that indicated these soils always produced erosion above the tolerable soil loss value.

(b) Tinkers Creek Subwatershed - Table A3.14 presents a summary of the critical erosion areas occurring in the Tinkers Creek subwatershed. As indicated only 5,750 acres (or 10 percent of the total subwatershed area) presently has a critical erosion problem. These areas produce about 160,000 tons of sediment per year. This represents approximately 93 percent of the total volume of sediment produced from sheet and rill erosion in the entire subwatershed. Of this 160,000 tons of sediment, it is estimated that approximately 79,000 tons is delivered to the Cuyahoga River system annually.

The majority of the sediment produced from sheet and rill erosion (66 percent) occurs on other land use. With the exception of Rittman silt loam, all the soil types listed under other land use are man disturbed areas with poor cover conditions. Because of the poor cover condition the soil surface is exposed to the full erosive force of the raindrop and resultant runoff.

Gravel pits in the Tinkers Creek subwatershed, which contribute 95,000 tons of sediment per year, have the highest rate of sheet and rill erosion (415 tons per acre per year) for any eroding area in the five subwatersheds studied for this report. The operation of a gravel pit leaves a large area bare and exposed. In addition, the overburden is normally spoiled around the periphery of the pit on steep slopes with no vegetation cover. Because the spoil material is disturbed and has lost its original soil structure, it is also easily eroded unless protected. These three factors combine to produce the high rates of erosion. Gravel pits are, however, easy to identify on the landscape and protective measures are inexpensive to implement.

Plates A3-13 to A3-18 in Appendix I are the OCAP maps produced by ODNR which show the areas of potential critical erosion. The specific critical combinations of land use and soil type requested in the OCAP system are shown on Table A3.15. These critical combinations were developed from Table A3.14, modified to account for differences in the land use catagories between the OCAP system and the EACP system.

The OCAP system identified a total potential critical erosion area of 8,482 acres or 15.63 percent of the total subwatershed area. These figures are slightly higher than the figures generated by the EACP system (5,750 acres or 10 percent of the total area). Again, the difference in results is due to the differences in land use classifications between the two systems.

As shown on Plates A3-13 and A3-14, potential critical erosion sites are scattered throughout the Tinkers Creek subwatershed with groupings or concentrations in certain areas. These concentrated areas occur primarily on commercial-industrial land, community services land and residential land currently under development, on other land such as gravel pits, landfills and made lands and on steep-sloped woodland areas along the tributary channels. Potential areas of critical erosion are noticeably absent along the flood plain of Tinkers Creek and in the marshy upper portion of the subwatershed near Pond Brook tributary and Streetsboro.

Table A3.14 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Tinkers Creek Subwatershed

Land Use	Soil Type		Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acres/ Yr.	Total[4/] Critical Tons for: WS/Yr.	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered to the River/Yr.
Other Land	EuC	Ellsworth urban complex	115	grassy	1	1.1	127		
	Mn	Mahoning urban complex	115	grassy	1	4.9	564		
	RsC2	Rittman silt loam	115	weeds	3	9.5	1,093		
	CF	Cut & Fill	115	weeds	1	17.7	2,036		
	CF	Cut & Fill	115	weeds	1	5.4	621		
	CF	Cut & Fill	230	bare	1	3.4	782		
	GP	Gravel Pit	230	bare	1	415.2	95,496		
	Md	Made Land	115	weeds	1	37.0	4,255		
	Md	Made Land	115	bare	1	14.5	1,688		
			1,265				106,662	50	53,331 tons
Commercial-Industrial Land	CF	Cut & Fill	115	woody & grass	1	1.4	161		
	CF	Cut & Fill	115	bare	1	5.8	667		
	ELC	Ellsworth silt loam	115	bare	3	71.8	8,257		
	ELF	Ellsworth silt loam	115	grass	3	18.4	2,116		
	MgB	Mahoning silt loam	115	bare	3	9.3	1,070		
	MgB	Mahoning silt loam	115	bare	3	17.9	2,059		
	Mn	Mahoning urban complex	115	woody & grass	1	1.5	173		
	Mn	Mahoning urban complex	115	bare	1	3.1	357		
			920				14,860	50	7,430 tons
Community Services Land	CF	Cut & Fill	115	weeds	1	1.8	207		
	CF	Cut & Fill	115	bare	1	75.1	8,637		
	CF	Cut & Fill	230	bare	1	4.5	1,035		
	RsC2	Rittman silt loam	115	woody, noncomm.	3	8.2	943		
	RsC2	Rittman silt loam	115	weeds	3	4.4	506		
			690				11,328	30	3,398 tons
Woodland	ELD	Ellsworth silt loam	115	woody	3	9.6	1,104		
	ELD2	Ellsworth silt loam	115	woody	2	10.5	1,208		
	ELE2	Ellsworth silt loam	230	woody	2	21.5	4,945		
	ELE2	Ellsworth silt loam	115	woody	2	23.3	2,679		
	ELF	Ellsworth silt loam	115	woody	3	24.4	2,806		
	RsC2	Rittman silt loam	115	woody	3	3.5	403		
	RsC2	Rittman silt loam	115	woody	3	24.4	2,806		
	RsC2	Rittman silt loam	230	woody	3	3.8	874		
	RsC2	Rittman silt loam	345	woody	3	3.0	1,035		
			1,495				17,860	70	12,502 tons

Table A3.14 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Tinkers Creek Subwatershed (Cont'd)

Land Use	Soil Type	Expanded [1/] Acres for Subwatershed	Cover Type	Tolerable [2/] Soil Loss Value (T)	Actual [3/] Tons/ Acres/ Year	Total [4/] Critical Tons for: WS/Year	Sediment [5/] Delivery Rate (Percent)	Quantity of Sediment Delivered to the River/Year
Wildlife Land	CF Cut & Fill	115	grassy	1	1.4	161		
	ELD2 Ellsworth silt loam	115	woody & grassy	2	8.8	1,012		
		230				1,173	40	469 tons
Residential Land	CpB Chili silt loam	115	bare	4	7.3	840		
	ELD2 Ellsworth silt loam	115	grassy	2	4.7	541		
	EuC Ellsworth urban comple:	230	bare	1	6.1	1,403		
	Fn Fitchville urban complex	115	bare	1	9.8	1,127		
		575				3,911	30	1,173 tons
Cropland	ELC2 Ellsworth silt loam	230	corn	3	11.2	2,576		
	MgB Mahoning silt loam	115	corn	3	6.7	771		
		345				3,347	20	669 tons
Pastureland	ELD2 Ellsworth silt loam	115	grassy	2	4.5	518		
		115				518	10	52 tons
Transportation	MgB Mahoning silt loam	115	grassy	3	7.3	840		
		115				840	50	420 tons
Totals for Tinkers Creek Subwatershed		5,750 acres (or 10 percent of the subwatershed area) presently has a critical erosion problem. [6/]				160,499 tons dislodged or 93 percent of the total tons dislodged from the total subwatershed area.		79,444 tons delivered/year

1/ 9.2 acres per sample point (from Table A3.11) divided by Tinkers Creek sampling rate of 8 percent and multiplied by number of data points encountered in the sample data which had the same land use, soil type and cover type with erosion above T.

2/ The maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely.

3/ Existing rate of sheet and rill erosion as determined by the Universal Soil Loss Equation.

4/ Expanded acres for subwatershed multiplied by rate of sheet and rill erosion.

5/ Estimated delivery rate of sediment produced from sheet and rill erosion to tributary stream (from Table A3.10).

6/ See Plates A3-13, and A3-14 in Appendix I for the location of critically eroding areas in the Tinkers Creek Subwatershed.

Table A3.15 - Critical Combinations of Land Use and Soil Type That Produce Erosion Above the Tolerable Soil Loss Value - Tinkers Creek Subwatershed 1/

Land Use	Soil Type	
1. Woodland/Wildlife	CF	Cut & Fill
	ELD	Ellsworth silt loam
	ELD2	Ellsworth silt loam
	ELE2	Ellsworth silt loam
	ELF	Ellswroth silt loam
	RsC2	Rittman silt loam
	RsC 2/	Rittman silt loam
2. Cropland/Pastureland/Grassland	ELC2	Ellsworth silt loam
	ELD2	Ellsworth silt loam
	MgB	Mahoning silt loam
3. Residential	CpB	Chili silt loam
	ELD2	Ellsworth silt loam
	EuC	Ellsworth urban complex
	Fn	Fitchville urban complex
4. Other Land	CF	Cut & Fill
	EuC	Ellsworth urban complex
	GP	Gravel Pit
	Md	Made Land
	MmB 2/	Mahoning urban complex
	Mn	Mahoning urban complex
	RsC2	Rittman silt loam
	RsC 2/	Rittman silt loam
5. Transportation	MgB	Mahoning silt loam
6. Commercial/Industrial Land	CF	Cut & Fill
	ELC	Ellsworth silt loam
	ELF	Ellsworth silt loam
	MgB	Mahoning silt loam
	Mn	Mahoning urban complex
	MmB 2/	Mahoning urban complex
7. Community Services Land	CF	Cut & Fill
	RsC2	Rittman silt loam
	RsC 2/	Rittman silt loam

1/ Critical combinations used in OCAP system to produce Plates A3-13 to A3-18 in Appendix I

2/ Soil types added to conform with soil type name changes made in the final classification and correlation of soil type symbols for the Cuyahoga County Soil Survey.

(c) Chippewa Creek Subwatershed - Table A3.16 presents a summary of the critical erosion areas occurring in the Chippewa Creek subwatershed. As indicated only 1,804 acres (or 16 percent of the total subwatershed area) presently has a critical erosion problem. These areas produce about 87,000 tons of sediment per year. This represents about 98 percent of the total volume of sediment produced from sheet and rill erosion in the entire subwatershed. Of this 87,000 tons of sediment, it is estimated that approximately 52,000 tons is delivered to the Cuyahoga River system annually.

The majority of the sediment produced from sheet and rill erosion (57 percent) occurs on recreation land use. All the soils listed under this land use are composed of silt and fine sandy loams which are highly erodible. They also have very steep slopes ranging from 12 percent to 50 percent. The combined effect of these two factors generate the high sediment yields.

The Geeburg-Mentor silt loam soil type has very high erosion rates ranging from 137 tons per acre per year to 375 tons per acre per year. This soil type was formed in clayey sediment deposited in the glacial lakes of the Wisconsin age. They have a tendency to go back into suspension if not adequately protected with a well-established and dense, vegetation cover. Since recreation land is subjected to intensive use this vegetation cover does not have sufficient time to establish itself.

Plates A3-19 to A3-21 in Appendix I are the OCAP maps produced by ODNR which show the areas of potential critical erosion. The specific critical combinations of land use and soil type requested in the OCAP system are shown on Table A3.17. These critical combinations were developed from Table A3.16 modified to account for differences in the land use catagories between the OCAP system and the EACP system.

The OCAP system identified a total potential critical erosion area of 2,353 acres, or 20.68 percent of the total subwatershed area. Again, these figures are slightly higher than the figures generated by the EACP system (1,804 acres or 16 percent of the total area) due to the differences in land use classification between the two systems.

As shown on Plate A3-19, the majority of the potential critical erosion sites occur in the lower (or eastern) portion of the subwatershed. The areas near the subwatershed boundary have flatter slopes and well-established vegetation cover and thus, were not identified as potential critical erosion areas.

Table A3.16 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Chippewa Creek Subwatershed

Land Use		Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Woodland	BrF	Brecksville silt loam	88	woody, comm.	3	12.5	1,103		
	ELC	Ellsworth silt loam	132	woody, comm.	3	11.2	1,482		
	ELE	Ellsworth silt loam	88	woody, comm.	3	14.8	1,305		
	ELF	Ellsworth silt loam	88	woody, comm.	3	14.8	1,305		
	GeF	Geeburg-Mentor silt loam	44	woody, comm.	2	152.1	6,708		
	Ct	Condit silty clay loam	132	woody, comm.	3	28.3	3,744		
			572				15,647	70	10,953 tons
Recreation	BrF	Brecksville silt loam	44	woody, comm.	3	56.2	2,478		
	BrF	Brecksville silt loam	44	woody, noncomm.	3	45.1	1,989		
	ELD	Ellsworth silt loam	44	woody, noncomm.	3	4.7	207		
	GeF	Geeburg-Mentor silt loam	44	woody, noncomm.	2	375.6	16,564		
	GeF	Geeburg-Mentor silt loam	44	woody, noncomm.	2	363.7	16,039		
	GeF	Geeburg-Mentor silt loam	88	woody, noncomm.	2	137.5	12,128		
			308				49,405	70	34,584 tons
Community Service	ELF	Ellsworth silt loam	44	woody, comm.	3	63.8	2,814		
	EuC	Ellsworth urban land complex	44	grassy	1	119.4	5,266		
	MgB	Mahoning silt loam	88	woody, noncomm.	3	11.4	1,006		
	Mn	Mahoning urban land complex	44	bare	1	12.8	565		
			220				9,651	30	2,895 tons
Residential	CF	Cut & Fill	44	bare	1	15.4	679		
	ELF	Ellsworth silt loam	44	woody, comm.	3	70.2	3,096		
	EuC	Ellsworth urban land complex	88	woody, noncomm.	1	30.6	2,699		
	EuC	Ellsworth urban land complex	44	wood-grass, noncomm.	1	65.6	2,899		
	RsC2	Rittman silt loam	44	weeds	3	3.2	141		
			264				9,504	30	2,851 tons

Table A3.16 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Chippewa Creek Subwatershed (Cont'd)

Land Use		Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Other Land	EuC	Ellworth urban land complex	44	bare	1	6.7	296		
	CF	Cut & Fill	132	grassy	1	1.9	251		
	CF	Cut & Fill	44	weeds	1	2.3	101		
	CF	Cut & Fill	44	weeds	1	4.0	176		
	CF	Cut & Fill	88	bare	1	11.5	1,014		
	Mn	Mahoning urban land complex	44	bare	1	3.5	154		
			396				1,992	50	996 tons
Wildlife	GeF	Geeburg-Mentor silt loam	44	wood-grass, non-comm.	2	11.8	520		
			44				520	40	208 tons
Totals for Chippewa Creek Subwatershed			1,804 acres (or 16 percent of the subwatershed area) presently has a critical erosion problem.[6/]				86,719 tons dislodged/year or 98 percent of the total tons dislodged from the total subwatershed area.		52,487 tons delivered/year

1/ 9.7 acres per sample point (from Table A3.11) divided by Chippewa Creek sampling rate of 22 percent and multiplied by number of data points encountered in the sample data which had the same land use, soil type and cover type with erosion above T.

2/ The maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely.

3/ Existing rate of sheet and rill erosion as determined by the Universal Soil Loss Equation.

4/ Expanded acres for subwatershed multiplied by rate of sheet and rill erosion.

5/ Estimated delivery rate of sediment produced from sheet and rill erosion to tributary stream (from Table A3.10).

6/ See Plate A3-19 in Appendix I for the location of critically eroding areas in the Chippewa Creek Subwatershed.

Table A3.17 - Critical Combinations of Land Use and Soil Type That Produce Erosion above the Tolerable Soil Loss Value - Chippewa Creek Subwatershed1/

Land Use	Soil Type	
1. Woodland/Wildlife/Recreation Land	BrF	Brecksville silt loam
	ELC	Ellsworth silt loam
	ELD	Ellsworth silt loam
	ELE	Ellsworth silt loam
	ELF	Ellsworth silt loam
	GeF	Geeburg-Mentor silt loam
	Ct	Condit silty clay loam
2. Community Service Land	ELF	Ellsworth silt loam
	EuC	Ellsworth urban land complex
	MgB	Mahoning silt loam
	Mn	Mahoning urban land complex
	MmB2/	Mahoning urban land complex
3. Other Land	CF	Cut & Fill
	EuC	Ellsworth urban land complex
	GP3/	Gravel pit
	Md3/	Made land
	Mn	Mahoning urban land complex
	MmB2/	Mahoning urban land complex
4. Residential	CF	Cut & Fill
	ELF	Ellsworth silt loam
	EuC	Ellsworth urban land complex
	RsC2	Rittman silt loam
	RsC2/	Rittman silt loam

1/ Critical combinations used in OCAP system to produce Plates A3-19 to A3-21 in Appendix I.

2/ Soil types added to conform with soil type name changes made in the final classification and correlation of soil type symbols for Cuyahoga County Soil Survey.

3/ Soil types added based on results of studies in other subwatersheds that indicated these soils always produced erosion above the tolerable soil loss value.

(d) Furnace Run Subwatershed - Table A3.18 presents a summary of the critical erosion areas occurring in the Furnace Run subwatershed. As indicated, 2,583 acres, or 23 percent of the total subwatershed area, presently has a critical erosion problem. This percentage was the highest for any of the five subwatersheds studied for this report. These areas produce approximately 175,000 tons of sediment per year. This represents about 97 percent of the total volume of sediment produced from sheet and rill erosion in the entire subwatershed. Of this 175,000 tons of sediment, it is estimated that approximately 115,000 tons is delivered to the Cuyahoga River system annually.

The majority of the sediment produced from sheet and rill erosion (85 percent) occurs on woodland land use. This land use is the primary land use in the Furnace Run subwatershed and accounts for 34 percent of the total land area, or 3,850 acres (see Table A3.4). Of this total, 50 percent (or 1,927 acres) currently has a critical erosion problem. This is the reason why this subwatershed has the highest percentage of critically eroding areas of any of the five subwatersheds studied for this report.

The eroding woodland areas exhibit a high rate of erosion for the following reasons: (1) all the soils listed in Table A3.18 are composed of silt and clay loams which are highly erodible; (2) the soils are on very steep slopes which are subject to slipping; and (3) there is an absence of understory canopy and litter duff on the ground surface, particularly where the dominant forest species are maple, ash, and tulip-poplar. It appears that the lack of understory canopy and litter duff is the most significant variable affecting the high rates of erosion. Other woodland areas with the same soil types and slopes were sampled which had significantly lower erosion rates. These areas had dominant forest species of either oak, hemlock, or white pine which provided an understory canopy, and an accumulation of litter duff on the forest floor.

The understory canopy and litter duff layer provides erosion protection in the following ways. The understory canopy intercepts the raindrops and significantly reduces its fall velocity and resultant impact energy on the ground surface. The litter duff layer provides a cushion which absorbs the impact energy of the raindrop before it comes in contact with the soil surface. This layer also acts as a sponge, absorbing and storing a portion of the rainfall and thus reducing the total amount of runoff produced. In addition, the litter duff layer provides a germination bed for understory species which in turn increases the protective understory canopy cover.

It is not known why the understory canopy and litter duff layer develops when the dominant forest species are either oak, hemlock or white pine, and is absent when the dominant species are maple, ash and tulip-poplar. It is theorized that this situation occurs because of the following cumulative effects:

(1) The leaf litter (the first layer of the litter duff) from maple, ash, and tulip-poplars decays rapidly (usually within six months) because of its chemical composition.

(2) The decomposed leaf litter (the second layer of the litter duff) is then washed off the steep slopes during spring rainfalls leaving the soil surface bare until a new leaf litter layer forms in the fall.

(3) Since the soil surface is exposed to the full erosive force of the raindrop and resultant runoff during late spring and summer (April to September) increased erosion occurs. In addition, because the duff layer is no longer present to act as a sponge, the amount of runoff also increases.

(4) Because of the increased erosion, very little, if any, topsoil is present. The absence of topsoil and litter duff prevents understory species from germinating and forming a protective understory canopy.

(5) In the absence of an understory canopy, the raindrop is not intercepted before it comes in contact with the soil surface, which increases rate of erosion and causes a cyclic compounding effect.

When the dominant forest species are oak, hemlock or white pine this cyclic action is interrupted since the litter duff layer decays at a much slower rate. Before the decomposed leaf litter layer is exposed to rainfall and the resultant runoff, new leaf litter layers have formed on top and protect it from being washed away.

It should be noted that man has greatly affected the erosion presently occurring in Furnace Run subwatershed through his exploitation of the existing natural resources. Man has selectively harvested most of the oak, hemlock, and white pine species that were originally present for shipbuilding, home construction, and construction of the Ohio Canal. This exploitation has continued up to the present.

Plates A3-22 to A3-24 in Appendix I are the OCAP maps produced by ODNR which show the areas of potential critical erosion. The specific critical combinations of land use and soil type requested in the OCAP system are shown on Table A3.19. These critical combinations were developed from Table A3.18, modified to account for differences in the land use catogories between the OCAP system and the EACP system.

The OCAP system identified a total potential critical erosion area of 4,538 acres, or 34.83 percent of the total subwatershed area. These figures are significantly higher than the figures generated by the EACP system (2,583 acres or 23 percent of the total area). Part of this difference is due to the differences in land use classification between the two systems. In addition, the EACP system indicated that significant sheet erosion occurs in woodland areas when the dominant forest species are maple, ash, and tulip-poplar but does not occur when the dominant forest species are oak, hemlock, or white pine. Since the OCAP system used aerial photography to determine land use, a distinction could not be made between the different forest species. Therefore, the OCAP system indicates potential critical erosion on all woodland areas regardless of forest species.

As shown on Plate A3-22, potential critical erosion areas are scattered throughout the entire subwatershed except near the subwatershed boundary.

However, due to the significant difference in critical erosion acreage figures between the OCAP system and the EACP system, all potential critical erosion areas identified may not have an actual critical erosion problem.

Table A3.18 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Furnace Run Subwatershed

Land Use	Soil Type		Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Woodland	CyE	Conotton-Oshtemo gravelly sandy loam	82	woody, comm.	3	54.8	4,494		
	ELC2	Ellsworth silt loam	287	woody, comm.	3	9.1	2,612		
	ELE2	Ellsworth silt loam	246	woody, comm.	2	40.2	9,889		
	ELF2	Ellsworth silt loam	861	woody, comm.	2	126.9	109,261		
	ELF2	Ellsworth silt loam	123	woody, noncomm.	2	71.4	8,782		
	GfD2	Glenford silt loam	41	woody, noncomm.	4	70.2	2,878		
	RsD2	Rittman silt loam	123	woody, comm.	3	5.5	677		
	RsE2	Rittman silt loam	82	woody, comm.	3	22.6	1,853		
	Rv	Rough broken land, clay and silt	41	woody, comm.	2	193.2	7,921		
	CyF	Conotton-Oshtemo gravelly sandy loam	41	grassy	3	8	328		
			1,927				148,695	70	104,087 tons
Wildlife	ELB	Ellsworth silt loam	82	woody, noncomm.	3	6.2	508		
	ELF2	Ellsworth silt loam	41	woody, noncomm.	2	39.9	1,636		
	ELE2	Ellsworth silt loam	41	woody, grassy	2	18.4	754		
	ELF2	Ellsworth silt loam	41	woody, noncomm.	2	91.2	3,739		
	ELF2	Ellsworth silt loam	164	woody-grassy, noncomm.	2	34.8	5,707		
	RsC2	Rittman silt loam	41	grassy	3	3.7	152		
	RsC2	Rittman silt loam	41	woody, noncomm.	3	32.5	1,333		
	RsD2	Rittman silt loam	41	woody, noncomm.	3	41.7	1,710		
	WaB	Wadsworth silt loam	41	woody, noncomm.	4	254.8	10,447		
			533				25,986	40	10,394 tons
Residential	ELF2	Ellsworth silt loam	41	woody, noncomm.	2	2.4	98		
			41				98	30	29 tons

Table A3.18 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Furnace Run Subwatershed (Cont'd)

Land Use	Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Recreation Land	CoD2 Chili loam	41 / 41	woody, comm	3	5.2	213 / 213	70	149 tons
Transportation Land	ELF2 Ellsworth silt loam	41 / 41	grassy	2	8.5	349 / 349	50	174 tons
Totals for Furnace Run Subwatershed		2,583 acres (or 23 percent of the subwatershed area) presently has a critical erosion problem.[6/]				175,341 tons dislodged/year or 97 percent of the total tons dislodged from the total subwatershed area.		114,833 tons delivered/year

1/ 10.2 acres per sample point (from Table A3.11) divided by Furnace Run sampling rate of 25 percent and multiplied by number of data points encountered in the sample data which had the same land use, soil type and cover type with erosion above T.

2/ The maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely.

3/ Existing rate of sheet and rill erosion as determined by the Universal Soil Loss Equation.

4/ Expanded acres for subwatershed multiplied by rate of sheet and rill erosion.

5/ Estimated delivery rate of sediment produced from sheet and rill erosion to tributary stream (from Table A3.10).

6/ See Plate A3-22 in Appendix I for the location of critically eroding areas in the Furnace Run Subwatershed.

Table A3.19 - Critical Combinations of Land Use and Soil Type That Produce Erosion Above the Tolerable Soil Loss Value - Furnace Run Subwatershed1/

Land Use	Soil Type	
1. Woodland/Wildlife/Recreation	CoD2	Chili loam
	CyE	Conotton-Oshtemo, gravelly sandy loam
	CyF	Conotton-Oshtemo, gravelly sandy loam
	ELB	Ellsworth silt loam
	ELC2	Ellsworth silt loam
	ELE2	Ellsworth silt loam
	ELF2	Ellsworth silt loam
	GFD2	Glenford silt loam
	RsC2/	Rittman silt loam
	RsC2	Rittman silt loam
	RsD2	Rittman silt loam
	RsE2	Rittman silt loam
	Rv	Rough broken land, clay & silt
	WaB	Wadsworth silt loam
2. Residential Land	ELF2	Ellsworth silt loam
3. Transportation Land	ELF2	Ellsworth silt loam
4. Other Land3/	CF3/	Cut & Fill
	GP3/	Gravel Pit
	Md3/	Made land

1/ Critical combinations used in OCAP system to produce Plates A3-22 to A3-24 in Appendix I.

2/ Soil types added to conform with soil type name changes made in the final classification and correlation of soil type symbols for Cuyahoga County Soil Survey.

3/ Soil types and land use added based on results of studies in other subwatersheds that indicated these soils always produced erosion above the tolerable soil loss value in combination with this land use.

(e) Local Drainage Subwatershed - Table A3.20 presents a summary of the critical erosion areas occurring in the local drainage subwatershed. As indicated, 12,922 acres, or 21 percent the total subwatershed area, presently has a critical erosion problem. This acreage was the highest of any of the five subwatersheds studied for this report and represents about 53 percent of the critically eroding areas for the entire five subwatershed study area.

The critically eroding areas in the local drainage subwatershed produce approximately 366,000 tons of sediment per year. This represents about 97 percent of the total volume of sediment produced from sheet and rill erosion in the entire subwatershed. Of this 366,000 tons of sediment, it is estimated that approximately 250,000 tons is delivered to the Cuyahoga River system annually.

The majority of the sediment produced from sheet and rill erosion (95 percent) occurs on woodland land use. This land use is the primary land use in the local drainage subwatershed and accounts for 34 percent of the total land area, or 20,953 acres (see Table A3.5). Of this total, 52 percent (or 10,920 acres) currently has a critical erosion problem.

The eroding woodland areas exhibit a high rate of erosion for the same reasons as listed for the Furnace Run subwatershed. These reasons are as follows: (1) all the soils are composed of silt and clay loams which are highly erodible; (2) the soils are on very steep slopes which are subject to slipping; and (3) there is an absence of understory canopy and litter duff on the ground surface particularly where the dominant forest species are maple, ash, and tulip-poplar. Again it appears that the absence of understory canopy and litter duff is the primary variable affecting the high rates of erosion. It should be noted, however, that erosion rates for woodland land use in the local drainage subwatershed are less than those listed in Table A3.18 for Furnace Run subwatershed. The reason for this was that oak species were present in greater numbers in the local drainage subwatershed. These oak species contributed a longer lasting duff layer but were not present in sufficient quantities to completely control erosion.

Plates A3-25 to A3-30 in Appendix I are the OCAP maps produced by ODNR which show the areas of potential critical erosion. The specific critical combinations of land use and soil type requested in the OCAP system are shown on Table A3.21. These critical combinations were developed from Table A3.20, modified to account for differences in the land use catagories between the OCAP system and the EACP system.

The OCAP system identified a total potential critical erosion area of 13,724 acres, or 21.62 percent of the total subwatershed area. These figures are in close agreement with the figures generated by the EACP system (12,922 acres or 21 percent of the total area). However, because there are differences in the OCAP and EACP land use classification systems and because critical erosion in forest areas is also dependent on the existing tree species, it was anticipated that the OCAP system would have identified a higher total acreage of potential critical erosion areas than the the EACP system. It is not known why this did not occur.

As shown on Plates A3-25 and A3-26, potential areas of critical erosion are again scattered throughout the entire subwatershed. There are, however, concentrations or groupings of critical erosion areas along the smaller tributary channels of the Cuyahoga River. In addition, the OCAP maps indicate that Summit County has a greater percentage of area having potential critical erosion than Cuyahoga County.

Table A3.20 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Local Drainage Subwatershed

Land Use		Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Woodland	BeF	Berks silt loam	91	woody, comm.	3	15.7	1,429		
	BrF	Brecksville silt loam	910	woody, comm.	3	29.9	27,209		
	OsF	Oshtemo sandy loam	182	woody, comm.	3	18.9	3,440		
	CyF	Conotton-Oshtemo Complex	455	woody, comm.	3	16.1	7,334		
	DkF	Dekalb sandy loam	455	woody, comm.	3	14.6	6,650		
	ELE2	Ellsworth silt loam	273	woody, comm.	2	5.4	1,476		
	ELF	Ellswroth silt loam	182	woody, comm.	3	9.2	1,676		
	ELF2	Ellsworth silt loam	1,365	woody, comm.	2	37.1	47,317		
	GbC2	Geeburg silt loam	182	woody, comm.	2	19.8	3,608		
	GeF	Geeburg-Mentor silt loam	1,729	woody, comm.	2	46.3	80,141		
	GfD2	Genford silt loam	728	woody, comm.	4	8.6	7,051		
	Rv	Rough broken land, clay & silt	3,640	woody, comm.	2	36.1	131,548		
	Rw	Rough broken land, silt & sand	728	woody, comm.	4	37.7	27,476		
			10,920				346,355	70	242,449 tons
Wildlife	BeF	Berks silt loam	91	woody, noncomm.	3	45.7	4,159		
	OsF	Oshtemo sandy loam	91	woody-grassy, noncomm.	3	4.0	364		
	ELE2	Ellsworth silt loam	273	woody-grassy, noncomm.	2	2.1	573		
	ELF2	Ellsworth silt loam	91	woody-grassy, noncomm.	2	4.6	419		
	GeF	Geeburg-Mentor silt loam	364	woody, noncomm.	2	16.9	6,152		
	Sc	Shale rock land	91	woody-grassy, noncomm.	1	35.1	3,194		
			1,001				14,861	40	5,944 tons

Table A3.20 - Summary of Critical Erosion Areas Above the Tolerable Soil Loss Value - Local Drainage Subwatershed (Cont'd)

Land Use	Soil Type	Expanded[1/] Acres for Subwatershed	Cover Type	Tolerable[2/] Soil Loss Value (T)	Actual[3/] Tons/ Acre/ Year	Total[4/] Critical Tons for WS/Year	Sediment[5/] Delivery Rate (Percent)	Quantity of Sediment Delivered To the River/Year
Residential	EuC Ellsworth urban land complex	455 455	grassy	1	5.1	2,321 2,321	30	696 tons
Other Land	GeF Geeburg-Mentor silt loam Ur Urban land	91 91 182	woody-comm. grassy	2 1	4.9 2.1	446 191 637	50	319 tons
Commercial-Industrial	Mn Mahoning urban land complex	91 91	weeds	1	6.0	546 546	50	273 tons
Recreation	Rv Rough broken land, clay & silt	91 91	grassy	2	2.8	255 255	70	179 tons
Pastureland	ELF2 Ellsworth silt loam	91 91	grassy	2	9.5	865 865	10	87 tons
Transportation	GfC2 Glenford silt loam	91 91	grassy	4	4.1	373 373	50	187 tons
Totals for Local Drainage Subwatershed		12,922 acres (or 21 percent of the subwatershed area) presently has a critical erosion problem. 6/				366,213 tons dislodged/year or 97 percent of the total tons dislodged from the total subwatershed area.		250,134 tons delivered/year

1/ 9.1 acres per sample point (from Table A3.11) divided by local drainage sampling rate of 10 percent and multiplied by number of data points encountered in the sample data which had the same land use, soil type and cover type with erosion above T.

2/ The maximum rate of soil erosion expressed in tons per acre per year that will permit a high level of crop productivity to be sustained economically and indefinitely.

3/ Existing rate of sheet and rill erosion as determined by the Universal Soil Loss Equation.

4/ Expanded acres for subwatershed multiplied by the rate of sheet and rill erosion.

5/ Estimated delivery rate of sediment produced from sheet and rill erosion to tributary stream (from Table A3.10).

6/ See Plates A3-25 and A3-26 in Appendix I for the location of critically eroding areas in the local drainage subwatershed.

Table A3.21 - Critical Combinations of Land Use and Soil Type That Produce Erosion Above the Tolerable Soil Loss Value - Local Drainage Subwatershed 1/

Land Use	Soil Type	
1. Woodland/Wildlife/Recreation	BeF	Berks silt loam
	BrF	Brecksville silt loam
	CyF	Conotton-Oshtemo complex
	DkF	Dekalb sandy loam
	ELE2	Ellsworth silt loam
	ELF	Ellsworth silt loam
	ELF2	Ellsworth silt loam
	GbC2	Geeburg silt loam
	GeF	Geeburg-Mentor silt loam
	GfD2	Glenford silt loam
	OsF	Oshtemo sandy loam
	Rv	Rough broken land, clay and silt
	Rw	Rough broken land, silt and sand
	Sc	Shale rock land
2. Cropland/Pastureland/Grassland	ELF2	Ellsworth silt loam
3. Residential	EuC	Ellsworth urban land complex
4. Other Land	CF 2/	Cut & Fill
	GP 2/	Gravel Pit
	GeF	Geeburg-Mentor silt loam
	Md 2/	Made land
	Ur	Urban land
5. Commercial-Industrial	Mn	Mahoning urban land complex
	MmB 3/	Mahoning urban land complex
6. Transportation	GfC2	Glenford silt loam

1/ Critical combinations used in OCAP system to produce Plates A3-25 to A3-30 in Appendix I.

2/ Soil types added based on results of studies in other subwatersheds that indicated these soils always produced erosion above the tolerable soil loss value.

3/ Soil types added to conform with soil type name changes made in the final classification and correlation of soil type symbols for Cuyahoga County Soil Survey.

(f) Summary and General Conclusions - Sheet and rill erosion from diffuse nonpoint sources is a very serious problem in the five subwatersheds which were studied for this report. As shown on Table A3.22, approximately 880,000 tons of sediment (or 590,000 cubic yards) is produced from sheet and rill erosion annually. Of this volume, 850,000 tons (or 570,000 cubic yards) is produced from critically eroding areas (areas which have actual sediment dislodgment above the tolerable soil loss value). These critically eroding areas occur on only 24,000 acres, or 16 percent of the total area. All other areas with erosion rates less than the tolerable soil loss value contribute an insignificant volume of sediment (four percent of the total volume) and can be deleted from further consideration.

As indicated on Table A3.22, the critically eroding areas in the local drainage subwatershed contribute the largest volume of sediment (approximately 366,000 tons per year or 43 percent of the total volume). This is very significant since the sediment load that it contributes to the river has an immediate impact due to its proximity. Critically eroding areas in Mud Brook subwatershed contribute the smallest volume of sediment (approximately 57,000 tons per year). However, this volume still represents a serious condition, especially when compared to the annual streambank erosion occurring in the study area as previously discussed.

It is estimated that of the 850,000 tons of sediment produced from critically eroding areas, 530,000 tons (or 350,000 cubic yards) is delivered to the Cuyahoga River system annually. In addition, because only the smaller suspended soil particles reach the river system, it is estimated that 100 percent of this volume reaches Cleveland Harbor. By comparing this volume of sediment delivered to the river system with the 860,000 cubic yards of sediment annually dredged from Cleveland Harbor, it can be concluded that the five subwatersheds studied for this report account for 41 percent of the total volume of sediment dredged. Therefore, in order to significantly reduce dredging costs at Cleveland harbor, an effective erosion control program must be implemented on the critically eroding areas in these five subwatersheds.

Plates A3-10 to A3-30 are the OCAP maps produced by ODNR which show the location of potential critically eroding areas in the five subwatersheds studied for this report. These plates are grouped into sets of three (one set per subwatershed). The first plate of each set locates the potential critical erosion areas on a USGS topographic map. The next two plates of each set show the soil type and land use for each eroding area, respectively.

The OCAP maps were produced by having the OCAP computer scan its land use and soil type data base and map out those areas that had the combinations of land use and soil type that characterized the critical erosion areas. These critical combinations were formulated from the data developed from the diffuse nonpoint source erosion study, and are different for each subwatershed. It should be noted, however, that due to the differences in land use catagories between the OCAP system and the EACP system (the system used in the erosion study), some modifications were required. These modifications were previously discussed.

The OCAP system identified a total potential critical erosion area of approximately 31,000 acres, or 20 percent of the total area for the five subwatersheds studied. These figures are slightly higher than the figures generated by the EACP system (24,000 acres or 16 percent of the total area). This difference is due to the differences in land use classifications between the two systems and because other variables (such as tree species) which were also important in characterizing critically eroding areas are not included in the OCAP computer data base. Therefore, the OCAP maps should be interpreted as potential areas of critical erosion only.

Table A3.23 presents a summary of the sheet and rill erosion occurring on critical eroding areas in the five subwatersheds studied for this report by land use. As indicated, the majority of the sediment produced (66 percent) occurs on woodland land use, primarily in the Furnace Run and local drainage subwatersheds. These areas exhibit a high rate of erosion for the following reasons: (1) all the soils that are eroding are composed of silt and clay loams which are highly erodible; (2) the soils are on very steep slopes which are subject to slipping; and (3) there is an absence of understory canopy and litter duff on the ground surface particularly where the dominant forest species are maple, ash, and tulip-poplar. It appears that the lack of understory canopy and litter duff (which act together to protect the forest floor from erosion) is the most significant variable affecting the high rates of erosion. Other woodland areas with the same soil types and slopes were sampled which had significantly lower erosion rates. These areas had dominant forest species of either oak, hemlock, or white pine which provided an understory canopy and an accumulation of litter duff on the forest floor.

Because of the significant amount of sheet and rill erosion occurring in woodland areas, the U. S. Forest Service and ODNR-Division of Forestry were contacted in the Summer of 1978 to obtain their views on this unique situation. Although some reservations were expressed about the accuracy of the numerical values calculated from the Universal Soil Loss Equation, it was recognized that serious erosion is occurring in the woodland area. Both agencies recommended that further study be conducted, particularly in the Furnace Run subwatershed, to verify the accuracy of the numerical results. In particular, they recommended the following:

(1) A streambank erosion study be conducted in Furnace Run and Wheatley Run (a tributary to Furnace Run).

(2) Identify and quantify gully erosion (identifiable nonpoint sources) along Wheatley Run.

(3) Reevaluate the volume of sheet and rill erosion occurring in Furnace Run subwatershed relative to the above findings.

These recommended study programs will be conducted during the Fall of 1979 and the results will be reported in the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

Pertinent correspondence from these two agencies outlining this proposed study program are included in Appendix G - "Pertinent Correspondence" as Exhibits G-4 and G-5.

The Universal Soil Loss Equation (USLE), the basic tool used in the Environmental Assessment Computer Program to estimate sheet and rill erosion, is an empirical formula that groups the numerous interrelated physical and management parameters that influence the rate of erosion into six major factors that can be expressed numerically. Although research has supplied information from which at least approximate values may be obtained, selection of these values relies on a subjective evaluation of the physical conditions of the site under study by field personnel. Therefore, the figures presented in this report may be at best only a relative indicator of the seriousness of the erosion problem. However, the Universal Soil Loss Equation is recognized as the most reliable method of quantifying potential soil movement that is currently available.

It should also be noted that the Universal Soil Loss Equation does not estimate the sediment loss due to wind erosion, which is of particular concern on agricultural land. However, because of the limited amount of agricultural land in the watershed (less than 10 percent in the five subwatersheds studied for this report), and because the majority of the soil types present in the watershed are moderately cohesive soils, wind erosion is not a significant problem and was, therefore, not investigated for this Preliminary Feasibility Report.

Table A3.22 - Summary of Total Dislodged Sediment vs. Total Sediment Dislodged from Critical Areas 1/

Subwatershed	Total Tons of Sediment Dislodged/ Year	Total Sub-watershed Acreage	Total Tons of Sediment Dis-lodged from Critical Areas/Year	Total Critical Area Acreage
Mud Brook	60,871	18,752	57,317	1,395
Tinkers Creek	173,098	54,784	160,499	5,750
Chippewa Creek	88,607	11,328	86,719	1,804
Furnace Run	180,507	11,328	175,341	2,583
Local Drainage	376,035	60,672	366,213	12,922
Total Area	879,118	156,864	846,089	24,454
	say 880,000 (or 590,000 cy/yr 2/)	say 157,000	say 850,000 3/ 4/ (or 570,000 cy/yr 2/)	say 24,000 5/

1/ Critical areas are defined as those areas which have actual sediment dislodgement above the tolerable soil loss value.

2/ Assumed unit weight of 110 lbs. per cubic foot.

3/ Of this 850,000 tons of sediment (570,000 cy) it is estimated that 530,000 tons (or 350,000 cy) is delivered to the Cuyahoga River system annually.

4/ Ninety six percent of the total sediment dislodged.

5/ Sixteen percent of the total area acreage.

Table A3.23 - Summary of Critical Erosion Areas by Land Use 1/

Land Use	Total Tons of Sediment Dislodged from Critical Areas/Year	Delivery Rate (Percent)	Delivered Tons/Year	Acres
Commercial-Industrial	15,406	50	7,703	1,011
Community Services	20,979	30	6,293	910
Cropland	12,150	20	2,430	750
Pastureland	1,383	10	139	206
Recreation Land	49,873	70	34,912	440
Transportation Land	1,562	50	781	247
Wildlife Land	42,837	40	17,135	1,853
Woodland	560,593	70	392,416	15,454
Other Land	125,472	50	62,736	2,248
Residential Land	15,834	30	4,749	1,335
Total	846,089		529,294	24,454 2/
	say 850,000		say 530,000	say 24,000

1/ Includes data only for the five subwatersheds of Mud Brook, Furnace Run, Chippewa Creek, Tinkers Creek and the local drainage of the Cuyahoga River.

2/ Sixteen percent of the five subwatershed areas.

(2) Identifiable Nonpoint Sources of Erosion - Identifiable nonpoint sources of erosion refer to those areas where highly visible gully erosion on disturbed areas is taking place. As previously mentioned, identification of these source areas was confined to the Standard Project Flood area for the Cuyahoga River. The reason for this decision was that the sediment produced in these source areas, due to their proximity to the river channel, is generally delivered directly to the river and causes an immediate impact on the river system.

Table A3.24 is a summary of the 36 identifiable nonpoint sources that were identified by aerial photo interpretation. The identification number is the location code of the site to be used with the river mile stationing system. For example, site 14-1 is river mile 14 and site one. Table A3.24 also shows the approximate size of the site and the sediment source type. As previously mentioned, these sources were not quantified for this PFR. The quantities will be determined during preparation of the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

The source types for these sites have been divided into four different land disturbances and are as follows:

(1) Construction related areas (highways and associated borrow and soil areas, industrial, commercial, and residential developed areas) (see Photo A3.11).

(2) Sand and gravel pits (see Photo A3.12).

(3) Surface mining or stripping of topsoil and subsoil (see Photo A3.13).

(4) Fill areas such as sanitary landfills, industrial waste fills, and excess or surplus soil fill from other excavated areas (see Photo A3.14).

In addition, Plates A3-31 to A3-32 in Appendix I show the location of these sites.

Table A3.24 - Summary of Identifiable Nonpoint Sources of Erosion Along the Cuyahoga River 1/ (river mile 13.8 to 40.25)

Identification No. 2/	Source Type	Approximate Size (Acres)
14-1	Construction Area	18
15-1	Filling & Dumping Area	12
15-2	Surface Mining Area	19
15-3	Sand and Gravel Pit	29
15-4	Surface Mining Area	5
16-1	Sand and Gravel Pit	50
17-1	Filling & Dumping Area	1
17-2	Construction Area	6
18-1	Surface Mining Area	25
18-2	Filling & Dumping Area	3
18-3	Filling & Dumping Area	7
20-1	Construction Area	9
21-1	Filling & Dumping Area	5
24-1	Surface Mining Area	36
25-1	Construction Area	25
25-2	Surface Mining Area	46
25-3	Sand and Gravel Pit	13
26-1	Filling & Dumping Area	4
26-2	Construction Area	30
26-3	Construction Area	2
27-1	Construction Area	4
27-2	Construction Area	40
27-3	Construction Area	5

Table A3.24 - Summary of Identifiable Nonpoint Sources of Erosion Along the Cuyahoga River 1/ (river mile 13.8 to 40.25) (Cont'd)

Identification No. 2/	Source Type	Approximate Size (Acres)
27-4	Construction Area	7
27-5	Construction Area	2
28-1	Construction Area	28
31-1	Sand and Gravel Pit	6
33-1	Sand and Gravel Pit	8
34-1	Surface Mining Area	32
34-2	Sand and Gravel Pit	5
36-1	Surface Mining Area	14
36-2	Surface Mining Area	1
38-1	Filling & Dumping Area	45
40-1	Filling & Dumping Area	3
40-2	Filling & Dumping Area	7
40-3	Sand and Gravel Pit	32
Total		584 acres

1/ See Plates A3-31 and A3-32 in Appendix I for the locations of each source.

2/ Each identifiable nonpoint source is identified by two sets of numbers. The first set of numbers refers to the river mile where the source is located. The second set refers to the particular site within that river mile.

Photo A3.11 - Identifiable nonpoint source of erosion: Construction Spoil Area (Identification No. 27-5), (SCS 11/78.)

Photo A3.12 - Identifiable nonpoint source of erosion: Gravel Pit Operation (Identification No. 40-3), (SCS 3/79.)

Photo A3.13 - Identifiable nonpoint source of erosion: Surface Mining of Topsoil (Identification No. 18-1), (SCS 7/79.)

Photo A3.14 - Identifiable nonpoint source of erosion: Sanitary Land Fill (Identification No. 38.1), (SCS 3/79.)

NCBED-DF 21 October 1980

MEMORANDUM FOR RECORD

SUBJECT: Buffalo District Position Paper on Verification of Streambank Erosion Studies for Cuyahoga River, Ohio Restoration Study

1. During NCD review of the Third Interim PFR for the subject study, specific concerns were raised regarding the estimate of sediment contribution from annual streambank erosion. Study results indicated that annual streambank erosion on the Cuyahoga River and its major tributaries produced about 52,000 cubic yards (or 78,000 tons) of sediment per year. Applying a delivery ratio of 90 percent, the quantity of sediment from annual streambank erosion represents approximately 5 percent of the sediment load dredged annually from the navigation channel and lakefront harbor at Cleveland, OH.

2. After reviewing the methodology used by the Soil Conservation Service (SCS) for estimating sediment contributions from annual streambank erosion, it was the position of some reviewers that this aspect of the study required verification. The main contention was that methods used by SCS field personnel to estimate bank erosion rates were dependent upon judgement and visual observations, thus, were not readily verifiable by a reviewer of the report.

3. Briefly summarizing the SCS method of estimating annual streambank erosion; streambanks along the main stem and primary tributaries were field surveyed and divided into short reaches having similar characteristics. These reaches were then classified as either eroding or noneroding. Streambanks classified eroding were further subdivided into reaches of significant bank erosion (estimated average annual recession rate greater than one foot per year) and not significant (less than one foot per year). At each eroding reach, various factors were recorded by SCS field personnel and of these various factors three were key variables used to quantify the amount of annual sediment contribution from each eroding reach. They were: (1) length of the eroding reach, (2) average bank height, and (3) average rate of annual lateral recession. Although the first two parameters could be directly measured in the field, the third parameter (bank erosion rate) was, in most instances, not directly measurable and appeared to require considerable judgement on the part of the SCS field data collector. Generally, the erosion rates assigned to specific sites were determined from visual observations, discussions with local landowners, examination of existing control points such as the Ohio Canal, adjacent noneroding reaches, etc. and, in areas where bank erosion was less significant, analysis of diameter changes in vegetative roots exposed along the banks. After all field data was collected, the volume of sediment contributed from each eroding site was computed by multiplying the length of the eroding reach by the bank height and the average rate of annual lateral recession estimated for that reach. A

cumulative sediment contribution from annual streambank erosion was computed and a 90 percent delivery ratio applied to estimate the quantity of available sediment which actually reaches Cleveland Harbor.

A sediment delivery ratio addresses the fact that not all sediment eroded from streambanks will be delivered to a downstream site. Some is deposited as overbank deposition, and still other sediment comprises a portion of point bar deposition downstream from the source of erosion. The sediment delivery ratio selected takes into account many factors (i.e., grain size of eroded soil material, transport capacity of the stream, amount of observed deposition, etc), and requires a great deal of judgement. Many rivers with actively eroding banks will maintain a constant width for years as bars build up on banks opposite to those eroding. In such cases, streambank erosion does not represent a primary sediment source, but is rather just a natural reworking of the flood plain alluvium.

4. In an attempt to check the conclusions reached in the Third Interim PFR regarding the estimated sediment contribution from annual streambank erosion, the District's Geotechnical Section performed a verification of this aspect of the study. It appeared that the critical factor to verify was the SCS estimate of annual lateral bank recession rate at the identified sites of erosion.

It was decided that an analysis of historical aerial photography of the river would be the simplest, most economical means of performing an independent verification. Aerial photography had been used by the SCS in the performance of their streambank erosion study, but only to identify erosion areas that had been historically active. As stated in the PFR (Appendix A, pg A-16), the scale of photography used for the streambank erosion studies was too large for accurate measurement of bank recession rates (1 inch = 2,000 feet).

5. The verification was initiated by obtaining aerial photography of the main stem Cuyahoga River for the flight years 1938 and 1979. Controlled scale photo enlargements were produced from original negatives to achieve a working scale of 1 inch = 660 feet. Contact prints were obtained for the 1938 photography, whereas film base positive transparencies were developed from the 1979 photography. A total of 18 eroding reaches, identified on Plates A 2-8 and A 2-9 of the Third Interim PFR, were randomly selected for verification. Utilizing available control points (i.e., road intersections, Ohio Barge Canal, structures, etc), the 1938 and 1979 bank lines were compiled. For each of the selected reaches, the 1938 and 1979 bank locations were compared and the amount of total lateral bank recession was directly measured. The annual erosion rate was determined by dividing the total measured recession by the 41-year interval between photos. In many instances, bank recession was nonuniform, thus it was necessary to take an integrated measurement in order to accurately define the bank recession in terms of a single value. Figure 1 provides a graphical display of the methodology used in the aerial photo analysis. In this display, eroding reach

22-1 from the Third Interim PFR is examined in detail to determine its historical rate of erosion. Note that Figure 1 is at the same scale used for all of the aerial photo analyses. An enlargement of Reach 22-1 is provided on Figure 2.

6. Table 1 lists the bank erosion rates measured from aerial photography for each of the 18 reaches used for the verification. These values are compared with the corresponding erosion rates estimated by the SCS study and presented in the Third Interim PFR. A review of Table 1 demonstrates there is good correspondence between the two sets of data. In 13 out of 18 reaches there is agreement to within one foot per year. Although there are some obvious discrepencies in a few cases, it appears those reaches which the SCS overestimated the long-term bank erosion rate are offset by other reaches which were underestimated. Had time and funds permitted it would have been advantageous to field check each of the reaches analyzed with aerial photography. It has been the District's experience that best results are achieved when aerial photo interpretation is coupled with field surveys performed for the purpose of "ground truthing." Apparent discrepencies which exist in the estimates of erosion for certain reaches (e.g. 26-3 and 37-2) might be explained by performing followup inspections to determine the existing condition of the individual streambanks.

7. As part of the streambank erosion verification, several reaches identified in the report as noneroding were also examined. The results of this analysis indicates there was in fact no measurable change in bank location at each of the areas checked. This was interpreted to represent no erosion or negligible erosion beyond accurate measurement at the scale of photography used.

8. To conclude, based on findings of the aerial photo verification of bank erosion rates, the District concurs with the SCS estimate of sediment contribution from annual streambank erosion as presented in the Third Interim PFR. Although the verification represents just a random sampling of the total number of eroding reaches identified and analyzed by the SCS, the results do indicate that the majority of the estimated streambank erosion rates are accurate to the degree necessary for making an assessment of the problem. No further verification studies are deemed necessary by the District in order to finalize the Third Interim PFR.

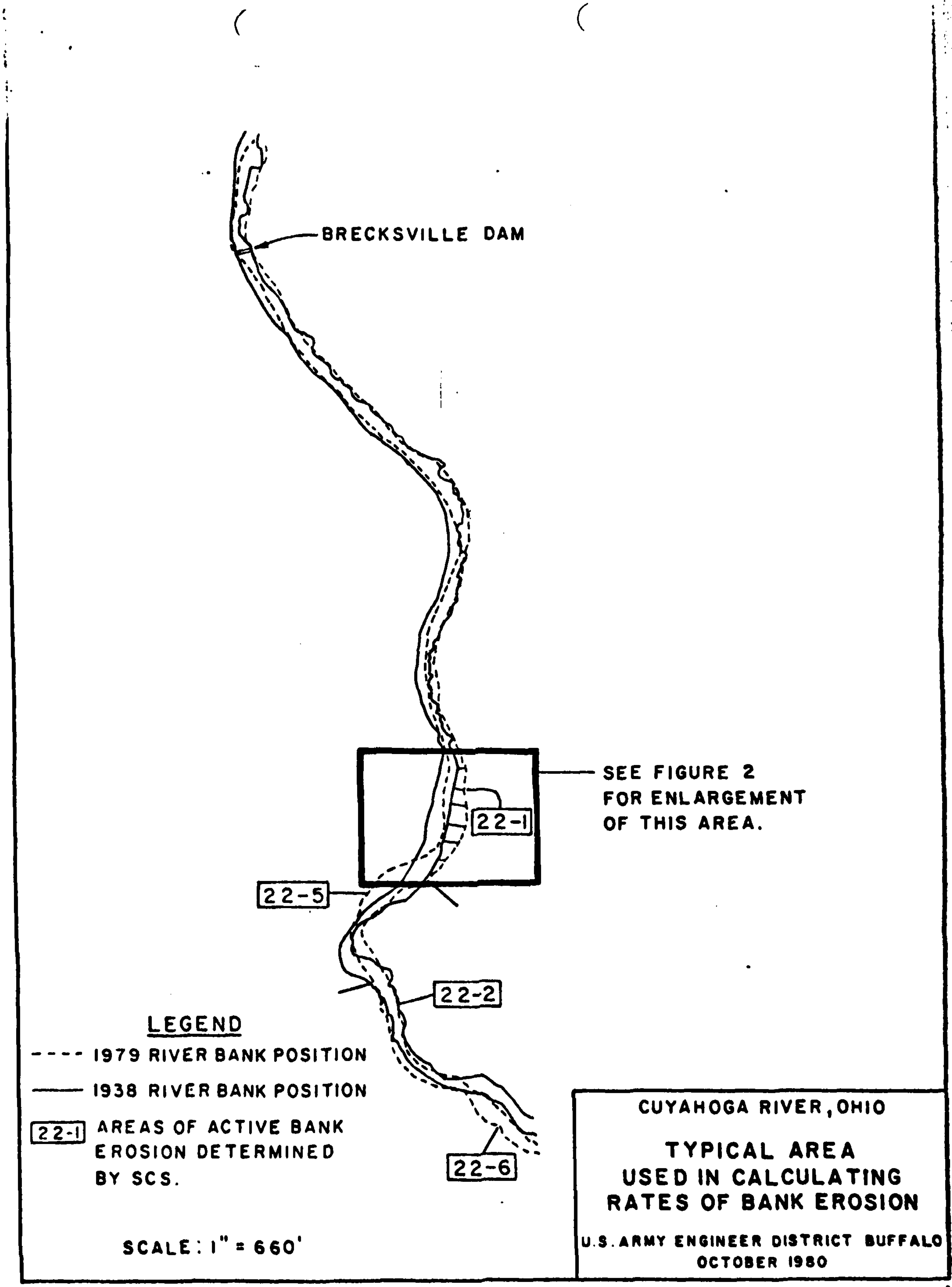
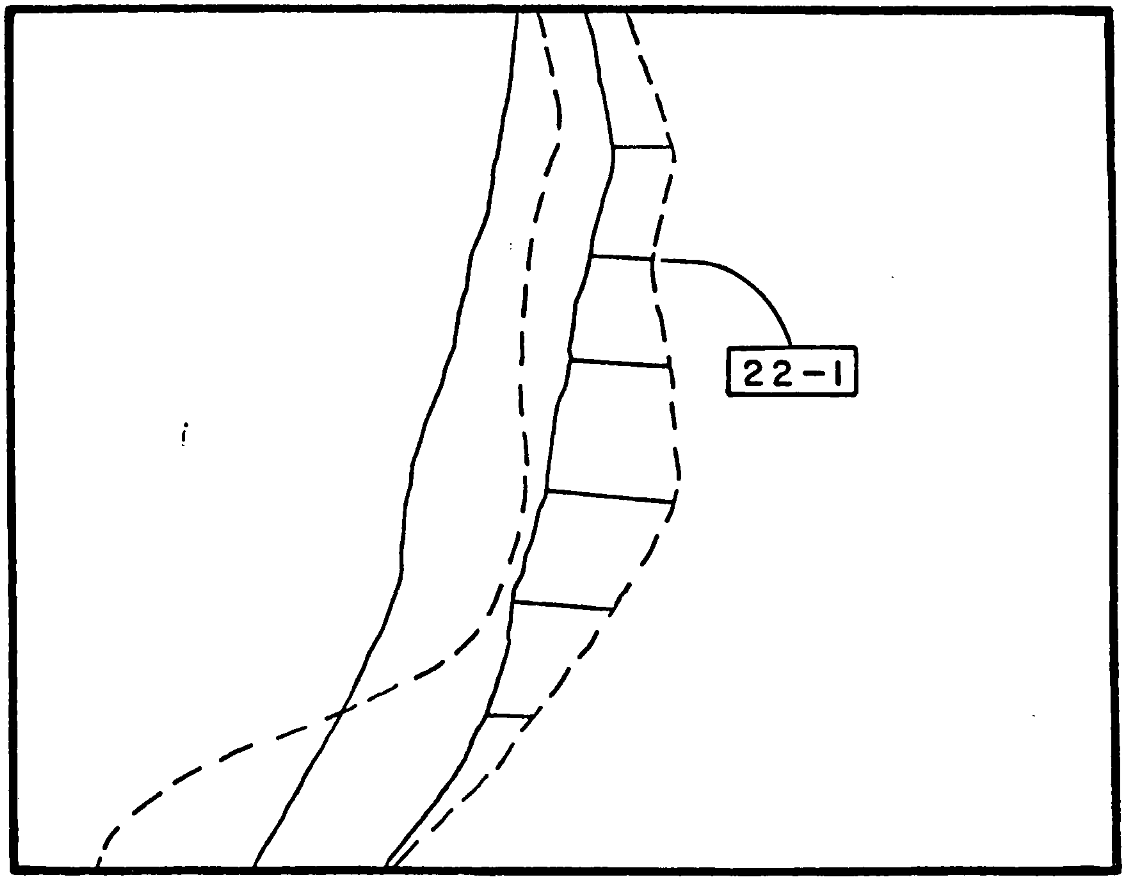

BRECKSVILLE DAM
SEE FIGURE 2 FOR ENLARGEMENT OF THIS AREA.
22-1
22-5
22-2
22-6
LEGEND
1979 RIVER BANK POSITION
1938 RIVER BANK POSITION
22-1 AREAS OF ACTIVE BANK EROSION DETERMINED BY SCS.
SCALE: 1" = 660'
CUYAHOGA RIVER, OHIO
TYPICAL AREA USED IN CALCULATING RATES OF BANK EROSION
U.S. ARMY ENGINEER DISTRICT BUFFALO
OCTOBER 1980

FIGURE 1



LEGEND

---- 1979 RIVER BANK POSITION

—— 1938 RIVER BANK POSITION

[22-1] AREAS OF ACTIVE BANK EROSION DETERMINED BY SCS.

APPROXIMATE SCALE: 1" = 150'

CUYAHOGA RIVER, OHIO

TYPICAL AREA USED IN CALCULATING RATES OF BANK EROSION

U.S. ARMY ENGINEER DISTRICT BUFFALO
OCTOBER 1980

FIGURE 2

Table 1 - Verification of Annual Lateral Recession Rates

Eroding Reach Identification Number	Total Lateral Recession 1938-1979 (Feet)	Average Rate of Annual Lateral Recession (Feet/Year) 1/	SCS Study Average Rate of Annual Lateral Recession (Feet/Year)
22 - 1	70	1.5	4.0
22 - 3	70	1.5	1.0
22 - 7	50	1.0	1.0
23 - 8	50	1.0	1.0
24 - 3	160	4.0	3.0
25 - 2	75	2.0	1.5
26 - 3	20	0.5 2/	5.0
28 - 1	85	2.0	1.5
30 - 4	40	1.0	2.0
32 - 2	175	4.5	2.5
32 - 4	20	0.5 2/	1.5
32 - 6	80	2.0	2.0
34 - 2	75	2.0	1.5
35 - 3	40	1.0	0.2
35 - 5	100	2.0	0.5
35 - 6	70	1.5	1.0
36 - 4	80	2.0	1.0
37 - 2	120	3.0	0.2
Average		1.8	1.7

1/ Recession rates are rounded to the nearest one-half foot.

2/ Value is approximate and may be outside the limits of accurate measurement at the scale of photography used (1 inch = 660 feet).

APPENDIX B

HYDROLOGY AND HYDRAULIC DESIGN

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

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APPENDIX B

HYDROLOGY AND HYDRAULIC DESIGN

B1. INTRODUCTION

The Cuyahoga River is about 100 miles long and drains some 810 square-miles of northeastern Ohio as shown on Figure B1.1. The river begins at an elevation of about 1,300 feet, several miles northeast of Burton in Geauga County, and flows in a southerly direction towards Hiram Rapids, where the direction changes southewesterly through Mantua, Kent, and Cuyahoga Falls, to the confluence with the Little Cuyahoga River at Akron. From Akron, the river flows north to Cleveland, to an elevation of about 570 feet. The lower 5.8 miles are part of an existing Federal navigation project for Cleveland Harbor, one of Lake Erie's major ports.

The main tributaries of the Cuyahoga River are: Big, Mill, Tinkers, and Chippawa Creeks; Mud Brook, Little Cuyahoga River, Congress Lake outlet (Breakneck Creek), and West Branch Cuyahoga River. The overall basin consists of rolling hills and many natural small lakes and ponds. A relatively distinct escarpment near Cleveland divides the basin between an upland plateau and the narrow lake plain.

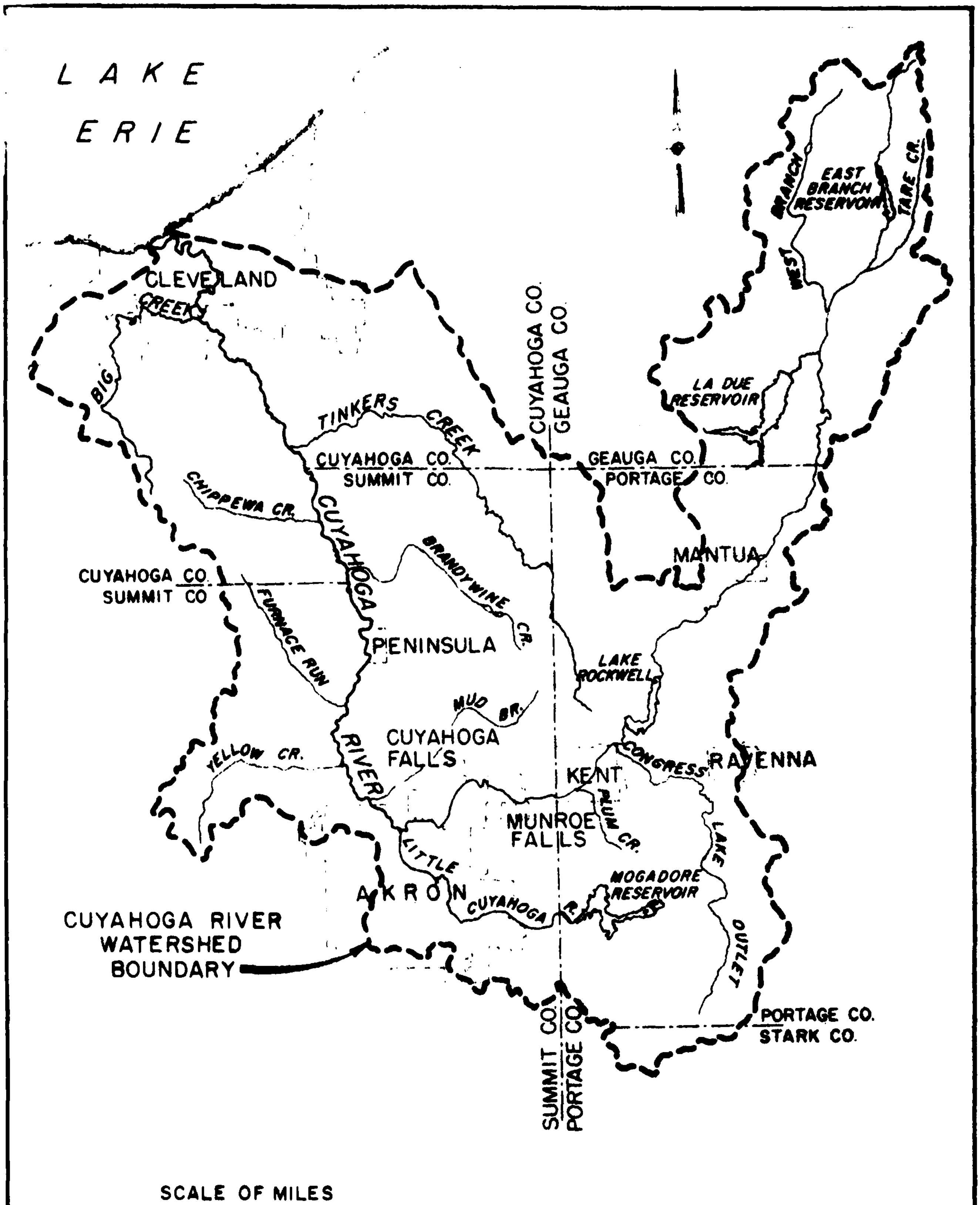
B2. HYDROLOGY

a. GENERAL - The information presented in this section has been prepared from data contained in the Corps of Engineers reports entitled, "Review of Reports for Flood Control and Allied Purposes, Cuyahoga River, Ohio (September 1969)" and the "Second Interim Feasibility Report on Cuyahoga River Flood Control Study (March 1976)." The data contained in these reports has not been undated for this preliminary feasibility investigation. Therefore, if the recommendation of this report is to continue into Stage 3 planning, additional study will be required.

b. CLIMATOLOGY - Available data from 34 climatological stations with varying lengths of record in and around the Cuyahoga River Basin, were used in studies of past storms. Eight of these stations are presently in operation. Records from these eight were used in compiling climatological data for the basin. Two of them are located within the basin and the other six are adjacent to it, including first order weather bureau stations at Cleveland Airport and Akron-Canton Airport. The locations of all climatological stations are shown on Figure B2.1. The period of record, type, and location of stations now in operation are given in Table B2.1.

c. PRECIPITATION [1/] - The weighted average annual precipitation for the eight climatological stations in and adjacent to the river basin is 36.70 inches. The weighted monthly averages vary from a minimum of 2.35 inches for

1/ Data based on years of record through 1968.



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

ORIENTATION MAP

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE BI.1

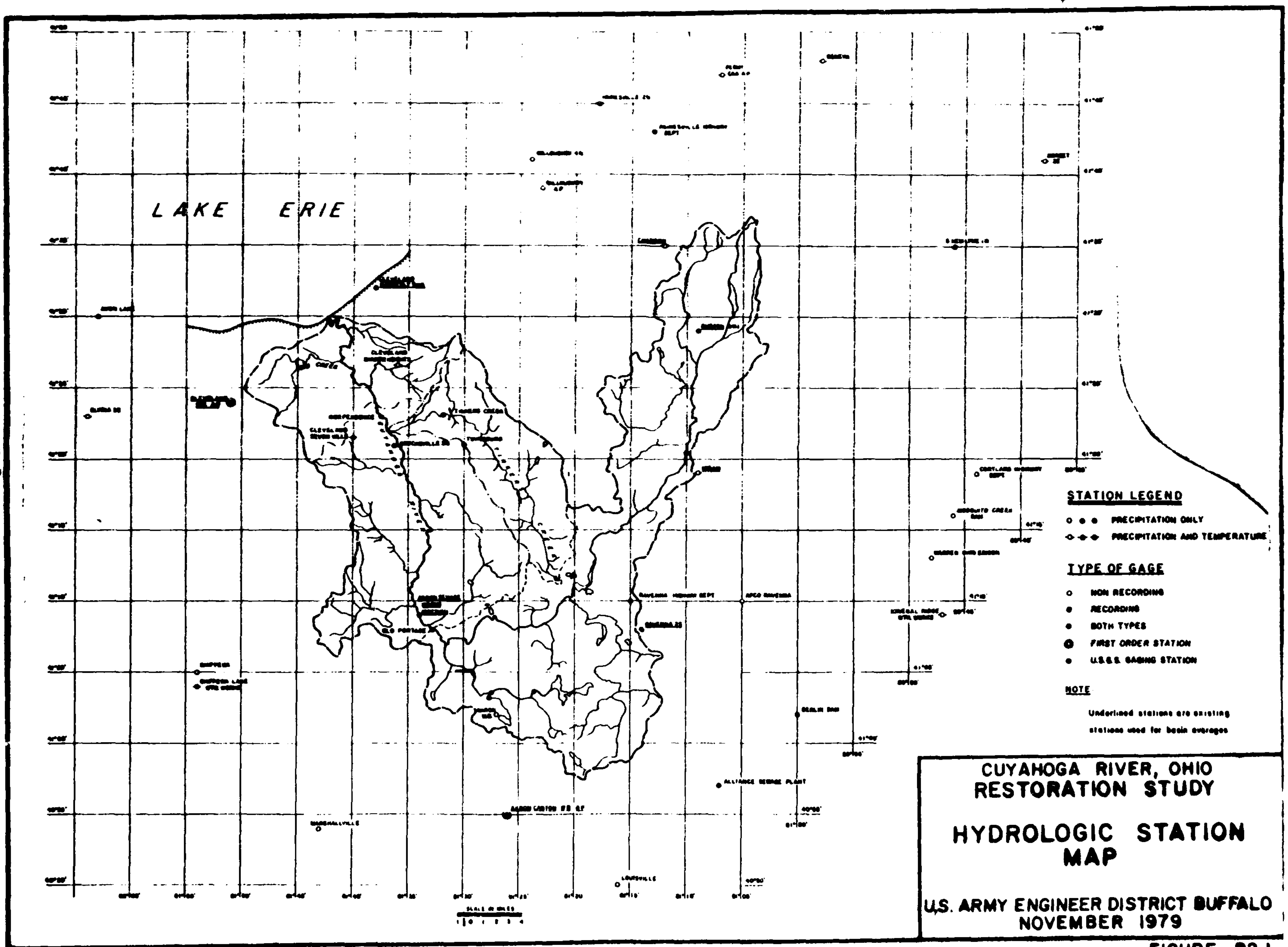

LAKE ERIE
STATION LEGEND
PRECIPITATION ONLY
PRECIPITATION AND TEMPERATURE
TYPE OF GAGE
NON RECORDING
RECORDING
BOTH TYPES
FIRST ORDER STATION
U.S.G.S. GAGING STATION
NOTE
Underlined stations are existing stations used for basin averages
CUYAHOGA RIVER, OHIO
RESTORATION STUDY
HYDROLOGIC STATION MAP
U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE B2.1

Table B2.1 - Climatological Stations in and Adjacent to the Cuyahoga River Basin 1/

Station Name	Index Number	Location: County	Location: Latitude	Location: Longitude	Location: Elevation	Type of Record (1)	Length of Record in Years (2)
Akron Canton W. B. Airport	0058	Summit	40°-55'	81°-26'	1,208	R,P,T,S	21 (3)
Akron Sewage Works	0059	Summit	41°-09'	81°-34'	760	R,P	20 (4)
Burton (1W)	1113	Geauga	41°-28'	81°-10'	1,160	R,P	18 (4)
Chardon	1458	Geauga	41°-35'	81°-12'	1,260	NR,P,T,S	23 (3)
Cleveland Easterly Swg	1651	Cuyahoga	41°-32'	81°-38'	592	R,P	13 (4)
Cleveland W. B. Airport	1657	Cuyahoga	41°-24'	81°-51'	777	R,P,T,S	96 (4)
Hiram	3780	Portage	41°-19'	81°-09'	1,260	NR,P,T,S	88 (3)
Ravenna (2S)	6949	Portage	41°-08'	81°-14'	1,100	R,P	21 (3)

(1) Type of record code: R = recording, NR = non-recording, P = precipitation, T = temprature, S = snowfall.

(2) All stations now in operation.

(3) Years of record through 1968.

(4) Years of record through 1967.

1/ SOURCE: Table from Corps 1969 report.

February to a maximum of 3.65 inches in April. The highest average monthly precipitation, 4.49 inches, occurs at Chardon in April, whereas the lowest average monthly precipitation, 1.71 inches, occurs at Cleveland Easterly Sewage Plant in December. Average annual precipitation varies from 30.62 inches at Cleveland Easterly Sewage Plant to 44.20 inches at Chardon. The monthly and yearly averages for each station are tabulated in Table B2.2.

d. SNOWFALL [1/] - The weighted average annual snowfall recorded at the four snowfall stations is 58.1 inches. Chardon has the highest average annual snowfall, 109.3 inches. Individual averages for the stations are shown in Table B2.3.

e. TEMPERATURE - The weighted average annual temperature in the river basin is 49.1 degrees Fahrenheit. January is the coldest month with an average temperature of 27.3 degrees, and July is the warmest month with an average temperature of 71.2 degrees. Average monthly and yearly temperatures for each of the four stations are listed in Table B2.4.

f. NOTABLE STORMS - Storms which resulted in serious flooding in the Cuyahoga River Basin include those of March 1913, June 1947, January 1952, October 1954, and January 1959.

(1) March 1913 Flood - The greatest precipitation, and the most destruction from high winds and floods to occur any month for which records are available, occurred in March 1913. Heavy rains occurred during the periods 13-15 and 20-21 March. These rains were only preliminary to the severe storm which developed during the period of 23-27 March. This storm extended from Texas to Lake Erie with its center over Bellefontaine, OH, 125 miles southwest of the Cuyahoga Basin. Two low-pressure centers combined to form a long trough of low pressure which caused excessive rainfall in Ohio and neighboring States for about 60 hours. Bellefontaine recorded a total of 11.16 inches of rainfall in 92 hours.

The Cuyahoga River Basin lay under the northeast edge of the storm and received an average of 8.86 inches of rainfall during the storm period. The estimated peak discharge, 30,000 cfs, for the March 1913 flood was determined by reconstitution of the flood hydrograph at the Independence gage site from rainfall records and unit hydrographs. Estimates of initial loss, infiltration, and base flow were included in the study. Total runoff at the gage site was estimated to have been 5.81 inches. The frequency of occurrence of a flood of such magnitude is estimated as less than once in 200 years.

[1/] Data based on years of record through 1968.

Table B2.2 - Average Monthly Precipitation 1/

Station	Years of Record	Precipitation, in Inches												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Akron Canton W. B. Airport	21	2.82	2.21	3.45	3.36	3.84	3.65	3.55	3.20	2.60	2.34	2.48	2.43	35.93
Akron Sewage Works	20	2.74	2.46	3.04	3.84	2.90	3.09	3.54	2.93	2.69	2.06	2.47	2.19	33.95
Burton (1W)	18	2.58	2.44	3.21	3.96	3.13	3.19	3.38	3.27	2.99	2.82	3.00	2.42	36.39
Chardon	23	3.54	2.78	3.82	4.49	3.90	3.88	3.72	3.94	3.02	3.66	4.12	3.33	44.20
Cleveland Easterly Swg.	13	1.93	1.77	2.13	3.39	2.93	3.21	3.11	3.20	2.26	2.31	2.67	1.71	30.62
Cleveland W. B. Airport	96	2.65	2.33	3.12	3.41	3.49	3.37	3.30	3.28	2.85	2.40	2.61	2.35	35.16
Hiram	88	2.84	2.39	3.32	3.71	3.94	4.03	3.69	3.40	2.94	2.77	2.87	2.61	38.51
Ravenna (2S)	21	2.88	2.16	2.91	3.59	3.41	3.41	3.94	3.02	2.58	2.25	2.93	2.32	35.40
Weighted Average		2.77	2.35	3.20	3.65	3.59	3.59	3.52	3.31	2.83	2.59	2.83	2.47	36.70

1/ SOURCE: Table from Corps 1969 report.

Table B2.3 - Average Monthly Snowfall 1/

Station	Years of Record	Snowfall, in Inches												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Akron Canton W. B. Airport	21	10.5	9.3	9.6	2.6	0.1	T				0.5	5.6	9.6	47.8
Chardon	23	25.2	21.2	18.6	5.2	T		T	T	T	1.1	13.5	24.5	109.3
Cleveland W. B. Airport	21	10.7	10.8	10.6	2.1	T					0.8	6.3	9.8	51.1
Hiram	72	9.8	10.3	7.0	2.4	T	T	T		T	0.7	5.7	10.8	46.7
Weighted Average		12.6	12.0	9.9	2.9	T	T	T	T	T	0.8	7.1	12.8	58.1

T = Trace

1/ SOURCE: Table from Corps 1969 report.

Table B2.4 - Mean Monthly Temperatures 1/

Station	Years of Record	Temperature, in Degrees Fahrenheit												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Akron Canton W. B. Airport	21	27.0	27.1	35.8	47.7	58.2	68.2	71.6	70.2	63.4	52.2	40.3	30.3	49.3
Chardon	23	26.1	27.2	35.4	47.6	57.3	67.1	70.8	69.4	63.3	53.5	40.9	29.4	49.0
Cleveland W. B. Airport	97	27.6	28.0	35.4	46.7	57.5	67.3	71.0	69.4	62.5	51.8	39.5	29.6	48.8
Hiram	84	27.5	27.6	35.4	47.5	58.2	67.7	71.5	70.0	63.7	53.1	40.5	29.9	49.4
Weighted Average		27.3	27.7	35.4	47.2	57.8	67.5	71.2	69.7	63.1	52.5	40.1	29.8	49.1

1/ SOURCE: Table from Corps 1969 report.

(2) January 1959 Flood - The greatest flood in recent years occurred on 22 January 1959. The January 1959 storm caused severe damage not only in the Cuyahoga River Basin but throughout the State of Ohio. The storm developed from a large mass of cold air over northwestern Canada, a flow of warmer air from the southwest and the associated frontal system. Heavy rains began on the 20th when the moisture-laden air from the south converged with the cold front. Although total rainfall for the storm was not excessive, intensities were high and runoff was increased by the frozen ground and the six-inch snow cover on the basin. The storm was centered approximately 150 miles southwest of the Cuyahoga River Basin and rainfall averaged 2.34 inches over the basin. Runoff from rainfall and snow melt averaged 2.94 inches. The United States Geological Survey (USGS) gaging station at Independence was inaccessible during the flood. A peak discharge of 24,800 cfs was calculated by the Geological Survey by contracted opening formula using high water marks at Hillside Road Bridge, 1.7 miles upstream of the gage. To check the reasonableness of the USGS peak discharge estimate, the flood was synthetically reconstituted by the Buffalo District. The synthetic peak discharge thus determined was 23,000 cfs. This check on the USGS calculations indicates that both solutions provide values which fall within narrow limits and which appear reasonable, based on the data used. The difference between the two solutions is probably the result of one or a combination of the following: false high water marks at Hillside Road Bridge caused by backwater effect from ice and debris dams; non-uniform area distribution of rainfall upstream of the gage causing the rainfall estimate to be low; or a low estimate of snow melt contributing to the flow. The January 1959 Flood on the Cuyahoga River is considered to be of Intermediate Regional Flood magnitude (100-year frequency).

(3) October 1954 Flood - Precipitation during the month of October 1954 was frequent and often heavy over the Cuyahoga River Basin. Many stations experienced record high precipitation for the month. Moderate to heavy rains fell over the basin during the period 10-14 October. A cold front moving from west to east through Ohio during the night of 14-15 October caused showers and thunderstorms over the basin. As the cold front reached the eastern border of Ohio, hurricane "Hazel" was approaching the Carolina coast, and the rain associated with the cold front was almost entirely west of the front. The hurricane's rain area spead rapidly inland and northward during the morning of the 15th to merge with the frontal rain before noon. Torrential rain fell in northeastern Ohio during the afternoon and evening of the 15th. Average rainfall over the basin was 4.47 inches and the total runoff at the Independence gage was estimated to have been 2.72 inches.

g. RUNOFF AND STREAM FLOW DATA - The United States Geological Survey has installed and operated 14 water-stage recording stations on the Cuyahoga River and its tributaries. Of these, seven were in operation when the Second Interim Report was prepared (1976). Peak discharges and runoff per square mile for four floods on the Cuyahoga River is given in Table B2.5 for each of these stations.

Table B2.5 - USGS Stage-Recording Gages in the Cuyahoga River Basin 1/

Stream	Location	Drainage area sq. mi.	Period of Record Years	Maximum Flood Discharge Peaks: June 1947 cfs	June 1947 cms 2/	January 1952 cfs	January 1952 cms 2/	October 1954 cfs	October 1954 cms 2/	January 1959 cfs	January 1959 cms 2/
Cuyahoga R.	Hiram Rapids, OH	151	1927-1935 1944-1974	1,510(1)	10.0	2,380	15.8	1,980	13.1	3,670	24.3
Cuyahoga R.	Old Portage, OH	404	1921-1035 1939-1974	3,100	7.7	4,540	11.2	2,180(1)	5.4	6,500	16.1
Cuyahoga R.	Independence, OH	707	1921-1923 1927-1935 1940-1974	12,600	18.0	11,200	16.0	14,200	20.2	24,800(4)	35.1
Little Cuyahoga	Mogadore, OH	17.3	1946-1974	143	10.0	136	9.5	27(1)	1.9	97	6.8
Ohio Canal	Independence, OH	None	1921-1923 1927-1935 1940-1974	70		88		145		277	
Big Creek	Cleveland, OH	35.3	1972-1974	N/A		N/A		N/A		N/A	
Tinkers Creek	Bedford, OH	83.9	1962-1974	(2)		(2)		6,150(3)	73.3	(2)	

1/ SOURCE: Second Interim Report.

2/ csm - Cubic feet per second per square mile.

(1) Estimated by U. S. Army Corps of Engineers, Buffalo District

(2) Gage was not in operation.

(3) Estimated from storm studies.

(4) Includes Ohio Canal discharge.

B3. HYDRAULIC DESIGN DATA

Hydraulic design data required for this report consisted of an average flow velocity to be used in design of proposed treatment methods to control streambank erosion. As discussed in Appendix C, design of each treatment method was based on one set of "average" conditions for the study area as a whole. This approach was considered adequate for this preliminary feasibility investigation although site specific refinement will be required during Stage 3 planning.

For design of proposed treatment methods, an average design velocity of 10.0 feet per second was used. From Table 10 of the "Flood Plain Information Report on the Cuyahoga River - Cuyahoga and Summit Counties, Ohio," (September 1976) prepared by the Buffalo District, the average channel velocity for the Intermediate Regional Flood (100-year flood) in the Cuyahoga River at Sagamore Road (river mile 18.6) is 6.6 feet per second. To this average velocity, a safety factor of 1.5 was applied resulting in a design velocity of 10.0 feet per second.

APPENDIX C

FORMULATION OF EROSION CONTROL ALTERNATIVES

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
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THIRD INTERIM PRELIMINARY FEASIBILITY REPORT
ON EROSION AND SEDIMENTATION

APPENDIX C

FORMULATION OF EROSION CONTROL ALTERNATIVES

C1. INTRODUCTION

The purpose of this appendix is to identify methods for controlling erosion and sedimentation in the Cuyahoga River Basin between Independence (river mile 13.8) and Old Portage (river mile 40.25) (see Figure A1.1 in Appendix A - "Study Area Orientation Map") through structural and nonstructural means. The specific areas susceptible to erosion and therefore requiring these protective works have been previously identified in Appendix A.

As was the case in Appendix A, the study area was divided into two study components or individual study areas: the channel component; and the upland watershed component. The alternatives developed for the channel component outline methods to reduce erosion of the streambanks in the Cuyahoga River and its six major tributaries within the study area. A series of management programs were developed to control erosion of the land surface in the 303 square-mile area of the upland watershed component. As explained in Section C3, these management programs for the upland component are general in nature and are not site specific. They were developed in order to inform local interests of the magnitude of the measures necessary to control erosion in the upland area. In addition, as explained in Section C3, the Corps will not implement these land management programs for controlling erosion in the upland area since this type of program is outside its scope of authority. Rather, the Corps will look to local interests to implement these programs.

The technical information presented herein was analyzed and evaluated by personnel of the U. S. Soil Conservation Service (SCS) in Columbus and Medina, OH. Therefore, techniques and methods used reflect SCS practices, regulations and technical manuals. The accompanying text material was a cooperative effort involving SCS and Buffalo District staff.

C2. CHANNEL COMPONENT

a. GENERAL - As previously outlined in Appendix A, the channel component study area consists of the main channel of the Cuyahoga River from Independence (river mile 13.8) to Old Portage (river mile 40.25),and the channels of the six major tributaries in this reach. These tributaries are Mud Brook, Brandywine Creek, and Tinkers Creek on the east side of the basin and Yellow Creek, Furnace Run, and Chippewa Creek on the west side of the basin. Two tributaries, Brandywine Creek (including Indian Creek, the major tributary of Brandywine Creek) and Tinkers Creek were studied over their entire length. The USGS sediment gaging data, as discussed in Appendix A, indicated that these two tributaries were the most significant sediment producers of the six tributaries studied. The remaining four tributaries were

only studied from their confluence with the Cuyahoga River upstream to the USGS sediment gaging station on each tributary. The study reaches for the Cuyahoga River and the six major tributaries are shown on Figure A2.1 in Appendix A.

The individual treatment methods selected to control streambank erosion are site specific based on the criteria discussed below. However, the design of each type of treatment was based on "average" conditions for the study area as a whole. These designs will therefore require site specific refinement during Stage 3 planning if the recommendation of this report is to continue into Stage 3.

Cost estimates have been prepared for each alternative formulated to control streambank erosion, as discussed in the following sections. The cost of each alternative will then be compared to benefits derived from implementation of each alternative in Appendix D "Economic Evaluation." The purpose of this evaluation will be to determine if further Federal interest in implementing a streambank stabilization program is warranted.

b. GENERAL DESIGN CONSIDERATIONS - The alternatives presented in this section consist of various combinations of the following general streambank treatment methods: (1) management treatment; (2) simple treatment; (3) trash and bar removal; (4) armoring treatment; and (5) bank reconstruction. The general designs presented in this section are based on Soil Conservation Service practices, regulations, and technical manuals. Technical manuals include the Soil Conservation Service "Engineering Field Manual" and the Soil Conservation Service "Technical Guide." These designs will require further modifications in Stage 3 planning if the recommendation of this report is to continue into Stage 3 based on Army Corps of Engineers criteria. Details of these general treatment methods are presented below:

(1) Management Treatment - Management treatment consists of annual maintenance activities to protect the existing vegetation cover where the rate of streambank erosion is negligible or within tolerable limits. Since the vegetation covering is the reason why these streambanks are now in a stable condition, if it is not properly maintained and protected an increase in streambank erosion can be expected.

Annual maintenance activities consist of the following: (1) fertilizing and mowing to maintain the existing vegetation cover in a vigorous state of growth; (2) semi-annual inspections to locate new areas of streambank erosion where the protective vegetation cover is disturbed by either natural or man-made causes; and (3) repair of the disturbed areas by either simple or armoring treatment based on the criteria for those two treatment methods presented below. Based on SCS experience from similar type work, the cost of these activities are estimated to be about $450 per acre per year or $8.25 per 100 feet of streambanks maintained per year (assumed average bank height of 8 feet). It should be noted that this is an average maintenance cost and no initial construction cost is required.

(2) Simple Treatment - Simple treatment consists of reestablishing native trees and grasses in areas where active streambank erosion is not

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CUYAHOGA RIVER, OHIO RESTORATION STUDY. THIRD INTERIM PRELIMINA--ETC(U)

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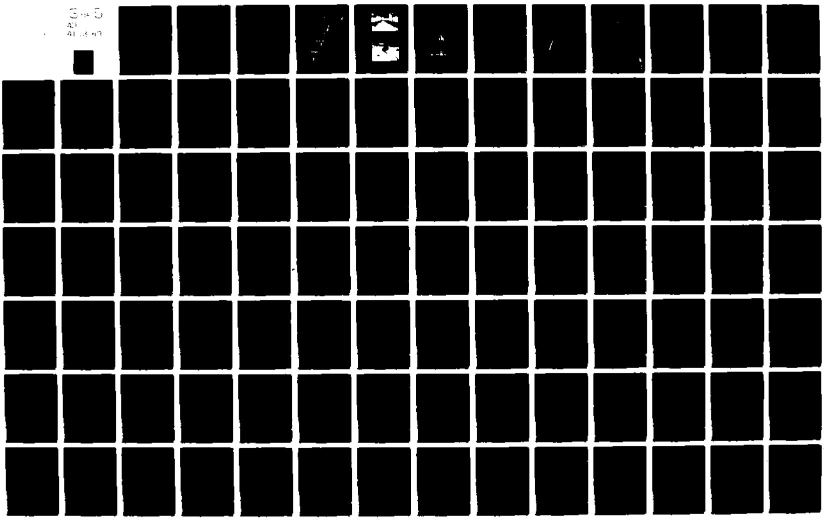


severe. As discussed in Appendix A, it was readily apparent that a healthy vegetative cover was successful in preventing streambank erosion in most instances. In every case where the streambanks had not been artificially protected, the stable streambanks had a healthy and heavy vegetative cover.

Simple treatment consists of the following activities: (1) removing any existing vegetative covering from the area to be protected; (2) cutting the streambank back to a stable slope (based on SCS experience and the properties of the soils reported in the Soil Survey Reports, this stable slope is assumed to be 1 vertical and 2 horizontal); (3) seeding and mulching the streambank; and (4) planting tree seedlings 12 to 18 inches high. Simple treatment will terminate at the top of the existing streambank. A typical cross-section of this type of treatment is shown in Figure C2.1.

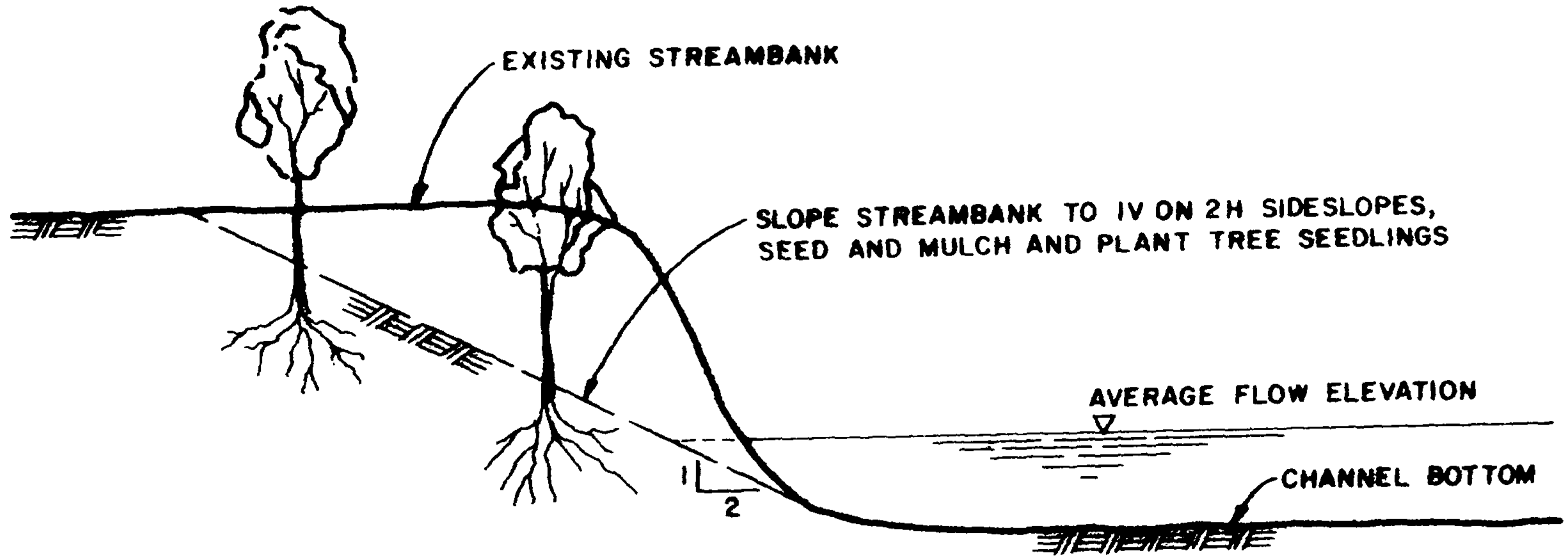
Based on SCS experience from similar projects, this type of treatment is estimated to cost approximately $200 per 100 feet of streambanks protected (assumed bank height of 8 feet). Maintenance activities would be the same as for management treatment.

In formulating alternative plans to control streambank erosion, simple treatment was the preferred treatment method for the following reasons: (1) the results of the streambank erosion study indicated that a healthy vegetative covering was successful in preventing streambank erosion in most instances; (2) this treatment method is the least environmentally damaging; and (3) this treatment method was the least costly streambank stabilization technique. Where the erosive forces of the streams were too great to be controlled by this type of treatment other types of structural measures were specified.

The criteria used to determine if simple treatment was suited for a particular reach was based on the estimated rate of annual lateral recession as discussed in Appendix A. It was assumed that when the estimated rate of annual lateral recession was less than or equal to 0.4 feet per year, simple treatment would prevent further streambank erosion. Normal Corps of Engineers practices base selection of this type of treatment method on flow velocity. Although flow velocity is related to the rate of streambank erosion, the streambank erosion study indicated other factors (vegetation covering, disturbance by man, etc.) affected the rate of streambank erosion. Since the estimated rate of annual lateral recession takes all these factors into account, it was used in this study.

(3) Trash and Bar Removal - As discussed in Appendix A, trash (dead trees, construction debris, etc.) and bedload bar buildup within the channels of the Cuyahoga River and several of its tributaries is a contributing factor to the high rates of annual lateral recession. Its removal will therefore aid in protecting the eroding streambanks. While there are many areas of trash and bar buildup within the stream channels, this treatment method would be limited to those areas where it increases the rate of annual lateral recession. All other areas would not be recommended for removal since these areas serve as fish and wildlife habitat.

The only activity involved in this type of treatment method is the actual removal of the trash and bedload bar buildup. Based on SCS experience with



CUYAHOGA RIVER, OHIO
RESTORATION STUDY
TYPICAL
SIMPLE TREATMENT
CROSS-SECTION

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE C2.1

similar type work trash removal is estimated to cost approximately $1,000 per site. Removal of bedload bar buildup is estimated to cost approximately $6,000 per site. Maintenance activities would consist of periodically removing any additional accumulation that may occur in the future.

(4) Armoring - This treatment method involves the placement of stone riprap along the banks of the streams where severe erosion is taking place. The areas where armoring is required will be limited to those areas where the erosive action of the stream is too strong to be controlled by simple treatment. For this report, any eroding streambank with an estimated annual lateral recession rate greater than 0.4 feet per year would therefore require armoring to prevent further streambank erosion.

Armoring treatment involves the following activities: (1) removing any existing vegetative covering from the area to be protected; (2) cutting the streambank back to a stable slope (based on SCS experience and the properties of the soils as reported in the Soil Survey Reports, this stable slope is assumed to be 2 horizontal and 1 vertical); (3) placement of a 6-inch gravel bedding to prevent the finer bank material from passing through the riprap; (4) placement of an 18-inch riprap layer; and (5) planting of flood plain tree species ranging in size from 4 feet to 12 feet high. The riprap will terminate at the top of the existing streambank. A typical cross section of this type of treatment is shown in Figure C2.2.

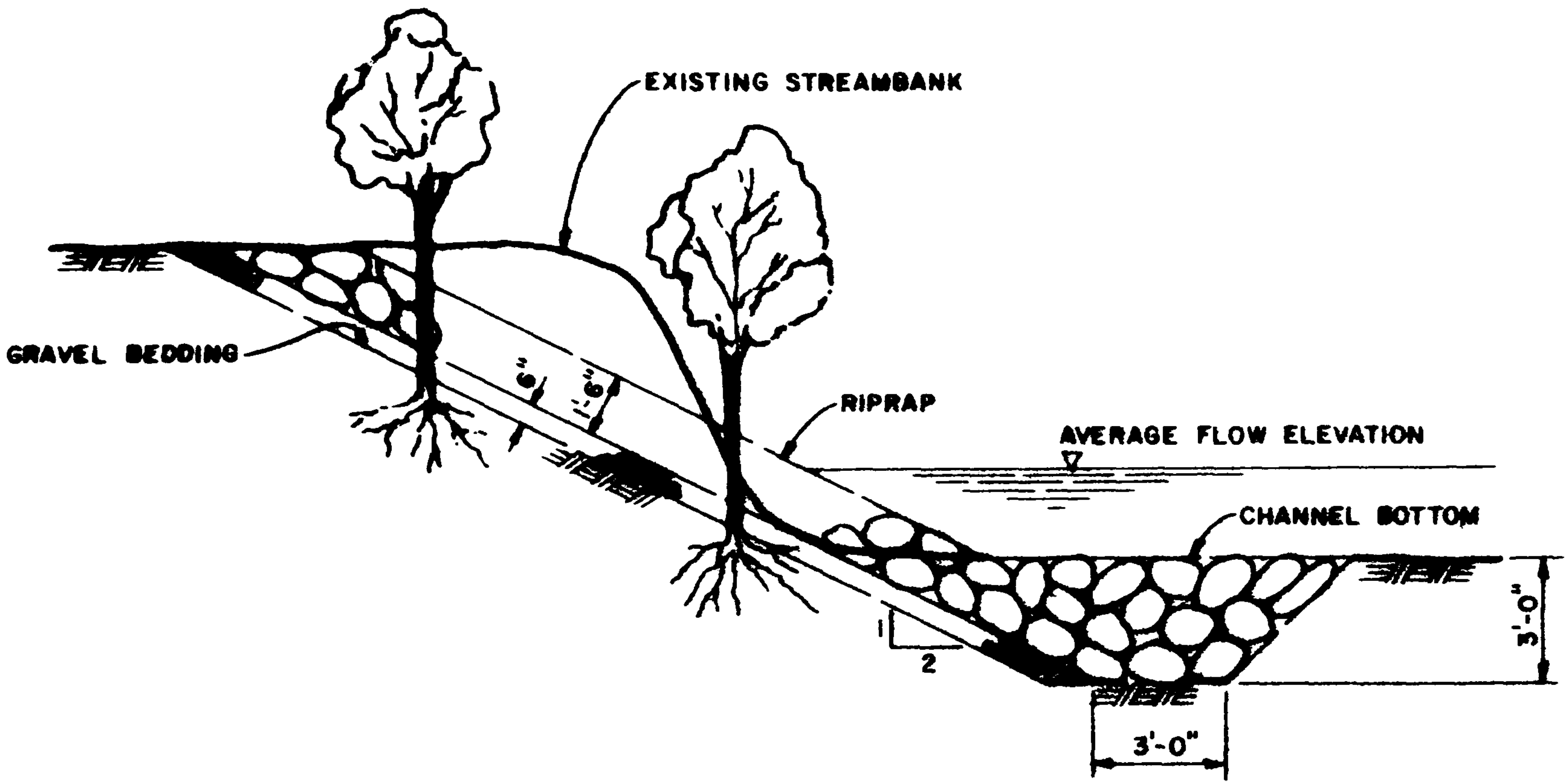
Based on SCS experience from similar projects, this type of treatment is estimated to cost approximately $5,500 per 100 feet of streambanks protected (assumed bank height of 8 feet). Annual maintenance activities would consist of periodically replacing any stone washed away.

Stone riprap was selected over other structural methods primarily due to its lower construction and maintenance costs and its ability to blend into the surrounding area. After the riprap has stabilized the streambanks, vegetation will begin to reestablish itself. Often, after one or two years, the vegetation will completely cover the riprap returning the streambank to a near natural condition. This is illustrated in Photos C2.1 and C2.2.

In designing for riprap size, an average velocity of 6.6 feet per second was used. The 6.6 feet per second velocity was selected based on the average channel velocity in the Cuyahoga River for the study reach between Independence and Old Portage for the 100-year flood as discussed in Appendix B. To this average velocity, a safety factor of 1.5 was applied resulting in a design velocity of 10 feet per second.

The rock size for riprap was obtained from the Isbash Curve shown in Figure C2.3. The curve was taken from the SCS "Engineering Field Manual," Chapter 16. For a velocity of 10 feet per second the following rock was selected:

Maximum Size	- 14 inches
Maximum Weight	- 175 pounds
Minimum Weight	- 25 pounds
Weight range of 75 percent of rock	- 50 to 175 pounds



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

TYPICAL
ARMORING TREATMENT
CROSS-SECTION

U.S. ARMY ENGINEER DISTRICT BUFFALO
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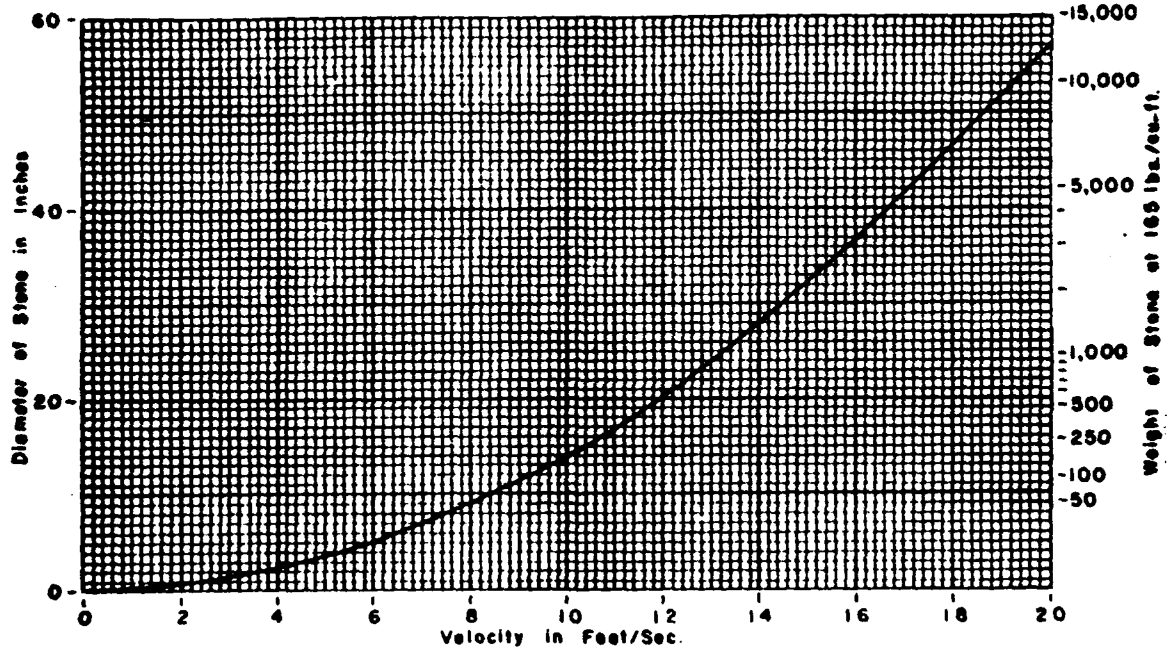
FIGURE C2.2

Photo C2.1 - Stone riprap immediately after construction (SCS 4/78.)

Photo C2.2 - Stone riprap 6 months after construction (SCS 10/78.)



NOTES:

1. BASED ON ISBASH CURVE
2. REPRODUCED FROM SCS ENGINEERING FIELD MANUAL

CUYAHOGA RIVER, OHIO
RESTORATION STUDY

MAXIMUM STONE SIZE FOR RIPRAP

U.S. ARMY ENGINEER DISTRICT BUFFALO
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FIGURE C2.3

The stability of this rock size on a 2:1 (horizontal to vertical) side slope was tested using the design curve shown in Figure C2.4. This curve was taken from "Hydraulic Engineering Circular No. 11," Bureau of Public Roads. Since 75 percent of the rock is 50 pounds or heavier, a 50-pound size was evaluated. From Figure C2.4, a 50-pound rock will withstand a velocity of 10 feet per second on a side slope of 2:1, and therefore the size distribution listed above was considered satisfactory for this preliminary design.

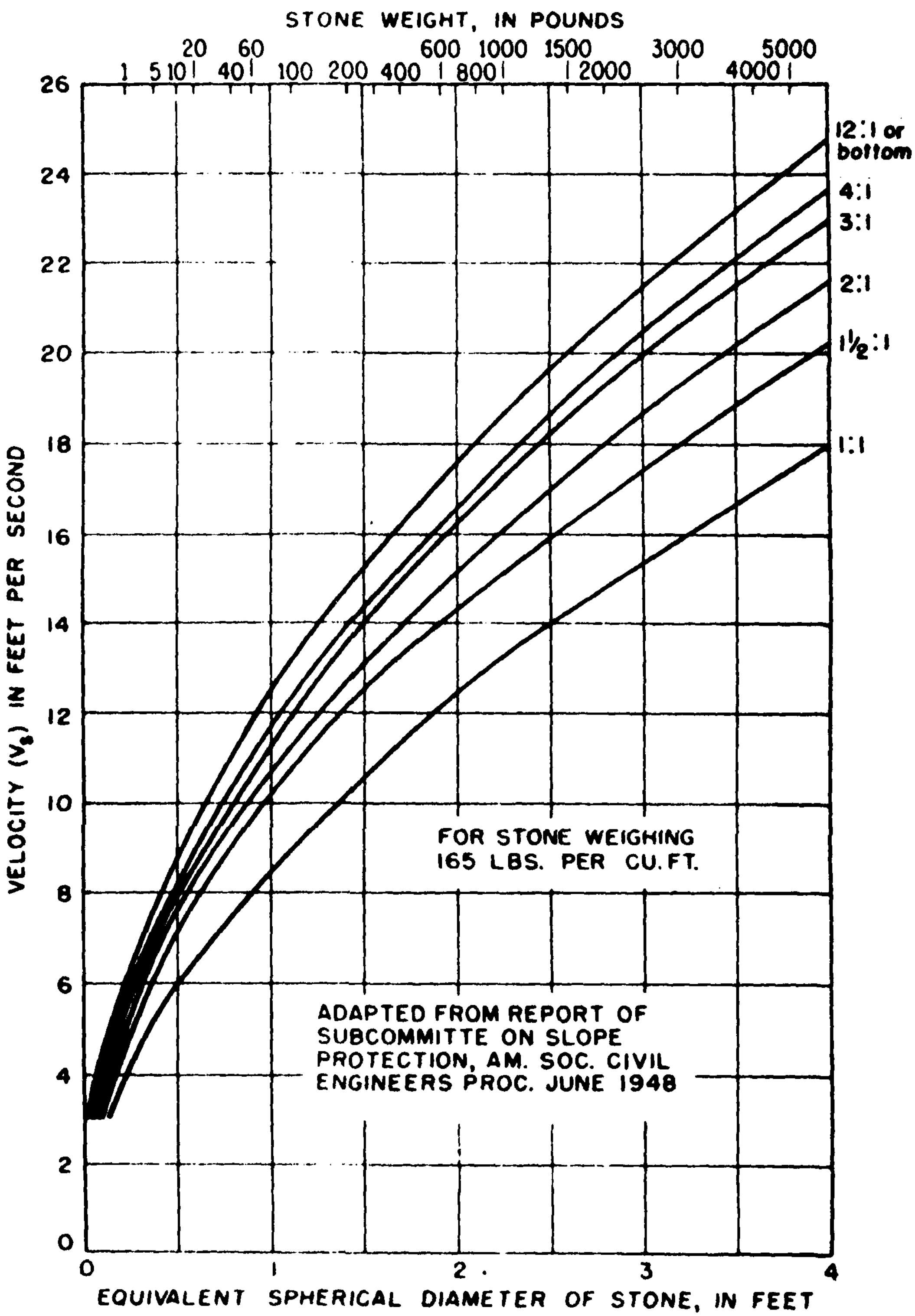
(5) Bank Reconstruction - As discussed in Appendix A, there are several locations along the Cuyahoga River where topsoil stripping operations have lowered the existing streambank. This allows the river to leave its bank during periods of above average flow and scour its flood plain. Although the quantity of sediment eroded from the flood plain during periods of overbank flow was not quantified for this report, it is believed to be significant in these areas because the topsoil stripping operation removes the protective vegetative covering.

Bank reconstruction consists of rebuilding the streambank to its original height (assumed to be the same as the opposite channel bank) to prevent this overbank flow and resultant flood plain scour. It involves the following activities: (1) removing any existing vegetative covering from the area where the bank will be reconstructed; (2) stripping of the top 6 inches of the existing ground to provide a uniform and firm foundation;
(3) reconstructing the bank using earth or other suitable material; and
(4) protecting the stream face of the reconstructed bank with either simple treatment or armoring treatment based on the selection criteria for these treatment methods and the existing rate of annual lateral recession. A typical cross section of this type of treatment is shown in Figure C2.5.

Based on SCS experience from similar projects, this type of treatment is estimated to cost approximately $1,000 per 100 feet of streambanks reconstructed (assumed height of 4 feet and simple treatment on the stream face of the reconstructed bank). Maintenance activities would consist of periodically repairing damage to the embankment and cover caused by major storm events.

c. ALTERNATIVES FORMULATED FOR STAGE 2 REPORT - As discussed in Section C of the Main Report "Formulation of Alternative Plans," preliminary evaluation of possible conceptual solutions indicated that only three alternatives warranted further consideration. These alternatives are:
(1) Alternative Plan No. 1 (Total Streambank Stabilization); (2) Alternative Plan No. 2 (Critical Area Streambank Stabilization); and (3) Alternative Plan No. 3 (Settling Basin). In addition, Alternative Plan No. 4 (No Action (Do Nothing) Plan) was also carried forward, as a basis for comparison of the above structural and nonstructural plans.

This section will present a detailed description of Alternative Plans No. 1 and No. 2 which were formulated for this report. As discussed in the Main Report, Alternative Plan No. 3 (Settling Basin) was originally formulated for the "First Interim Report" of the Cuyahoga River Restoration Study. Additional study on this alternative was limited to reevaluating its feasibility in light of current conditions within the study area. This is



NOTE:

REPRODUCED FROM HYDRAULIC ENGINEERING CIRCULAR NO. 11, BUREAU OF PUBLIC ROADS

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
STONE SIZES THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

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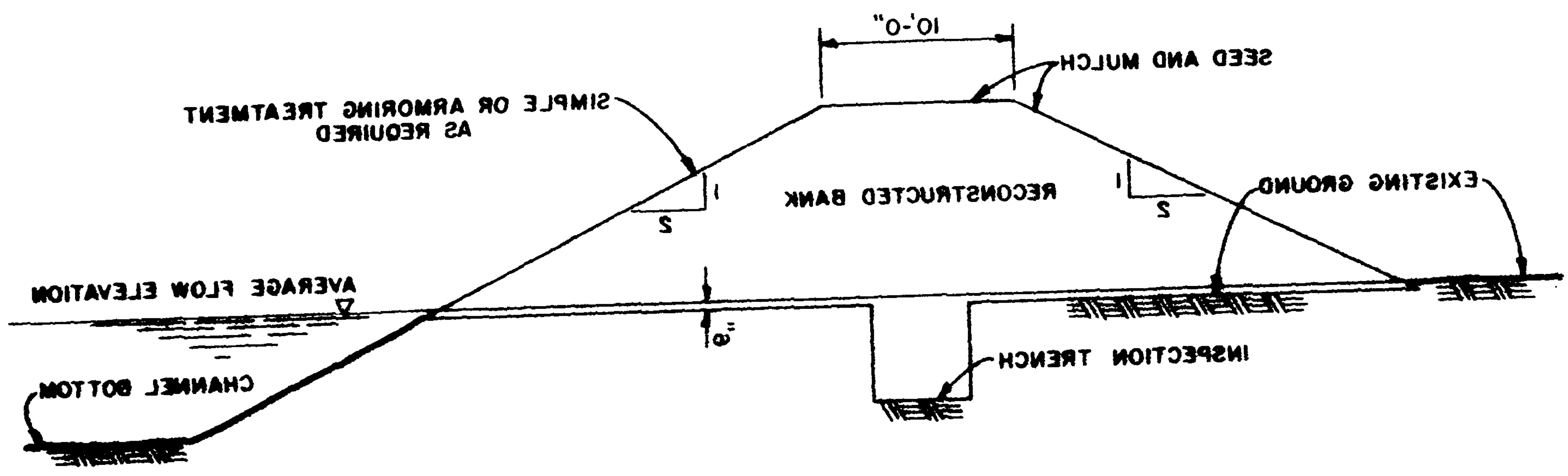
FIGURE C2.4



CUYAHOGA RIVER, OHIO
RESTORATION STUDY

TYPICAL
BANK RECONSTRUCTION
CROSS-SECTION

U.S. ARMY ENGINEER DISTRICT BUFFALO
NOVEMBER 1979

FIGURE 2.23

described in sufficient detail in Section D of the Main Report "Assessment and Evaluation of Preliminary Plans."

(1) Alternative Plan No. 1 (Total Streambank Stabilization) - Alternative Plan No. 1 was formulated to control all existing and potential annual streambank erosion and prevent the formation of the seven potential meander changes along the banks of the Cuyahoga River and its six major tributaries within the channel component study area (see Figure A2.1 in Appendix A). The existing sources of annual streambank erosion and the seven potential meander changes were previously located and quantified in Appendix A., Section A.2.

The results of the studies presented in Appendix A indicated that annual streambank erosion annually produces about 52,000 cubic yards of sediment (see Table A2.22). Of this 52,000 cubic yards of sediment, it is estimated that approximately 47,000 cubic yards is transported to Cleveland Harbor and requires yearly maintenance dredging. The studies also indicated that of the 143 miles of streambanks studied for this report (71.5 river/stream miles), only 22.7 miles, or 16 percent of the streambanks were actively eroding (see Table A2.21). These actively eroding streambanks are dispersed throughout the entire study area. Areas of major streambank erosion were identified between river miles 13.8 to 15.1, 18.0 to 20.0, 22.0 to 25.0, 26.0 to 27.0, and 30.0 to 33.0 on the Cuyhoga River, stream mile 0.0 to 0.8 on Yellow Creek, stream mile 0.0 to 1.5 on Furnace Run, stream mile 1.0 to 2.0 on Brandywine Creek, and between stream miles 1.0 to 2.0 and 11.0 to 12.0 on Tinkers Creek. The studies also indicated that there were seven locations on the Cuyahoga River (river mile 23.3, 25.3, 25.7, 26.1, 34.8(a), 34.8(b), and 39.0) where the existing high rate of annual streambank erosion (annual lateral recession) was likely to produce a change in the course of the river (potential meander change). If these potential meander changes were to occur, they would introduce an additional 125,000 cubic yards of sediment into the river system (see Table A2.24). The first objective considered in formulating Alternative Plan No. 1 was therefore to control the 22.7 miles of actively eroding streambanks and the seven potential meander changes, and thus prevent the introduction of the resultant sediment load into the river system.

The results of the studies presented in Appendix A also indicated that there were several sites where damage to local roads and railroad facilities of the Baltimore and Ohio Railroad would occur in the future because of the high rates of annual lateral recession at these locations. Local roads that are endangered occur at river mile 24.6 and 35.0 on the Cuyahoga River. Railroad facilities that are endangered occur at river mile 14.8 and 26.2 on the Cuyahoga River, stream mile 0.4 on Furnace Run and stream mile 0.2 on Yellow Creek. By controlling annual streambank erosion at these sites, damage to the local roads and railroad facilities will also be prevented.

The plan that was formulated to control the 22.7 miles of actively eroding streambanks and the seven potential meander changes consisted of either simple treatment or armoring treatment based on the criteria previously outlined. For example, at eroding Reach 16-2 on the Cuyahoga River with an

estimated annual lateral recession rate of 0.3 feet per year, simple treatment was selected. Conversely, at eroding Reach 16-1 on the Cuyahoga River with an estimated annual lateral recession rate of 1.5 feet per year, armoring treatment was selected. In all cases, armoring treatment was selected at the locations of the seven potential meander changes. The specific locations where each treatment method was selected is discussed below by stream.

(a) Cuyahoga River (River Mile 13.8 to 40.25) - Of the 53 miles of streambanks studied for this report (26.5 river miles), 14.4 streambank miles, or 27 percent, were identified as actively eroding. Simple treatment was selected to control 4.4 streambank miles, or 30 percent of the eroding streambanks, and armoring treatment was selected for the remaining 10.0 streambank miles, or 70 percent (including the armoring treatment required to control the seven potential meander changes). The specific locations where each type of treatment method is required are shown on Tables C2.1 and C2.2. These tables also present the estimated quantity of each treatment method that would be required at each specified location. These quantities will be used in the next section of this appendix in determining the first cost of construction for Alternative Plan No. 1.

In addition to the treatment methods outlined above, 0.6 miles of trash and bar removal and 0.7 miles of bank reconstruction were included in Alternative Plan No. 1 on the Cuyahoga River. Trash and bedload bar buildup was identified as a contributing factor to the high rates of annual lateral recession at several locations. Its removal will therefore aid in protecting the eroding streambanks. The specific locations where trash and bar removal is required are shown on Table C2.3. It should be noted that the presently eroding streambank will still require armoring treatment to prevent future streambank erosion. This armoring treatment has been included in Table C2.2.

Bank reconstruction is required to prevent overbank flow in areas where the streambanks have been lowered by topsoil stripping operations. Although the quantity of sediment eroded from these areas during periods of overbank flow was not quantified for this report, it is believed to be significant since these areas have no vegetative cover and are thus susceptible to erosion. The seven specific locations on the Cuyahoga River requiring this type of treatment are presented in Table C2.4. The required protection on the stream side of the reconstructed bank was based on the existing rate of annual lateral recession at each location. For the reconstructed banks at river mile 16.2, 25.3, and 25.7 on the west bank and at river mile 24.3 on the east bank, armoring treatment will be required because the existing rates of annual lateral recession are greater than 0.4 feet per year and is included in Table C2.2. Since there is presently no annual streambank erosion at river mile 15.5, 24.4, and 25.2 on the west bank, the stream side of the reconstructed bank will be protected with grass.

In conclusion, the required streambank treatment needs for Alternative Plan No. 1 on the Cuyahoga River includes 4.4 miles of simple treatment, 10.0 miles of armoring treatment, 0.6 miles of trash and bar removal, and 0.7 miles of bank reconstruction.

Table C2.1 - Alternative Plan No. 1: Simple Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
13.8 to 15.1	16-2	None		None
15.1 to 16.0		None		None
16.0 to 17.0	16-2	700	8	0.05
		700		0.05
17.0 to 18.0		None		None
18.0 to 19.0	18-2	900	8	0.17
		900		0.17
19.0 to 20.0		None		None
20.0 to 21.0	20-1	500	10	0.12
		500		0.12
21.0 to 22.0	None			None
22.0 to 25.0	22-2	2,700	8	0.50
	22-6	2,000	8	0.34
	23-1	1,300	8	0.24
	23-3	900	7	0.14
	23-4	600	6	0.08
	23-7	1,300	6.5	0.20
	23-12	500	8	0.10
	24-2	900	7	0.14
		10,200		1.74
25.0 to 26.0		None		None
26.0 to 27.0		None		None

Table C2.1 - Alternative Plan No. 1: Simple Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
27.0 to 28.0		None		None
28.0 to 29.0		None		None
29.0 to 30.0		None		None
30.0 to 32.0		None		None
32.0 to 33.0	32-3	800	4.5	0.08
	32-5	600	5	0.07
	32-8	800	5	0.10
	32-9	600	5	0.07
		2,800		0.32
33.0 to 34.0	33-1	400	7	0.06
	33-4	300	6	0.04
	33-5	200	9	0.04
		900		0.14
34.0 to 35.0	34-3	400	10	0.09
	34-4	300	7	0.05
	34-5	100	8	0.02
		800		0.16
35.0 to 36.0	35-2	800	8	0.15
	35-3	400	8	0.07
	35-4	300	8	0.06
	35-7	400	8	0.07
	35-8	400	8	0.07

Table C2.1 - Alternative Plan No. 1: Simple Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
	35-9	400	12	0.11
		2,700		0.53
36.0 to 37.0	36-2	200	8	0.04
	36-3	300	12	0.08
		500		0.12
37.0 to 38.0	37-1	300	15	0.10
	37-2	600	10	0.12
		900		0.22
38.0 to 39.0	38-2	300	7	0.05
		300		0.05
39.0 to 40.25	39-4	400	11	0.10
	40-1	1,500	13	0.45
		1,900		0.55
Total		23,100		4.17

1/ Simple treatment required = length required X average bank height.

Table C2.2 - Alternative Plan No. 1: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

River Section (by river mile)	Eroding Reach: Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
13.8 to 15.1	14-1	500	11	1,045	280
	14-2	1,000	9	1,850	480
	14-3	800	10	2,192	416
	14-4	1,000	9	1,850	480
		3,300		6,937	1,656
15.1 to 16.0	15-1	600	8	1,038	264
	15-2	1,400	8	2,422	616
		2,000		3,460	880
16.0 to 17.0	16-1	900	9 2/	1,665	432
		900		1,665	432
17.0 to 18.0	17-1	300	15	771	216
	17-2	800	8	1,384	352
	17-3	800	7	1,288	320
		1,900		3,443	888
18.0 to 19.0	18-1	1,400	9	2,590	672
	18-3	500	9	1,310	240
	18-4	500	10	985	260
	18-5	600	9	1,110	288
		3,000		5,995	1,460
19.0 to 20.0	19-1	600	18	1,758	504
	19-2	1,200	14	2,940	816
	19-3	900	13	2,097	576

Table C2.2 - Alternative Plan No. 1: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
		2,700		6,795	1,896
20.0 to 21.0		None		None	None
21.0 to 22.0		None		None	None
22.0 to 25.0	22-1	600	4	750	168
	22-3	1,300	8	2,249	572
	22-4	500	8	865	220
	22-5	700	8	1,211	308
	22-7	1,300	8	2,249	572
	23-2	500	9	1,310	240
	23-5	600	8	1,038	264
	23-6	300	8	519	132
	23-8	1,800	8	3,114	792
	23-9	900	7	1,449	360
	23-10	600	7	966	240
	23-11	600	8	1,038	264
	23-13	1,100	10	2,167	572
	24-1	800	7 3/	1,288	320
	24-3	900	8	1,557	396
		12,500		21,770	5,420
25.0 to 26.0	25-1	1,900	4.6	2,512	578
	25-2	600	6	894	216

Table C2.2 - Alternative Plan No. 1: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	25-3	1,000	8 2/	1,394	328
	25-4	1,200	8 2/	1,692	400
		4,700		6,492	1,522
26.0 to 27.0	26-1	300	8	519	132
	26-2	1,000	8	1,730	440
	26-3	300	30	1,311	396
	26-4	300	5	411	96
	26-5	600	8	1,038	264
		2,500		5,009	1,328
27.0 to 28.0		None		None	None
28.0 to 29.0	28-1	1,400	4	1,750	392
	28-2	300	6	447	108
		1,700		2,197	500
29.0 to 30.0		None		None	None
30.0 to 32.0	30-1	1,100	6	1,639	396
	30-2	600	5.5	858	204
	30-3	600	4.5	786	180
	30-4	1,400	5	1,918	448
	31-1	900	6	1,341	324
	31-2	1,200	5.5	1,716	408
	31-3	1,700	6.3	2,594	632

Table C2.2 - Alternative Plan No. 1: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	31-4	600	4.5	786	180
		8,100		11,638	2,772
32.0 to 33.0	32-1	400	7.5	668	168
	32-2	1,500	5	2,055	480
	32-4	500	17	1,405	400
	32-6	300	8	519	132
	32-7	700	3.5	833	182
		3,400		5,480	1,362
33.0 to 34.0	33-2	600	7	966	240
	33-3	500	7	805	200
		1,100		1,771	440
34.0 to 35.0	34-1 4/	200	7	322	80
	34-2	500	9	1,310	240
		700		1,632	320
35.0 to 36.0	35-1	300	7	483	120
	35-5	500	8	865	220
	35-6	300	8	519	132
		1,100		1,867	472
36.0 to 37.0	36-1	200	8	346	88
	36-4	700	7	1,127	280
		900		1,473	368

Table C2.2 - Alternative Plan No. 1: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
37.0 to 38.0	37-3	300	8	519	132
		300		519	132
38.0 to 39.0	38-1	300	8	519	132
	38-3	700	8	1,211	308
	38-4	100	30	437	132
		1,100		2,167	572
39.0 to 40.2	39-1	400	6	596	144
	39-2	500	25	1,885	560
	39-3	400	8	692	176
		1,300		3,173	880
Total		53,200		93,483	23,300

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.
2/ Includes an additional 4 feet of height to protect face of reconstructed bank.
3/ Includes an additional 5 feet of height to protect face of reconstructed bank.
4/ Riprap required to prevent future meander change in the river.

Table C2.3 - Alternative Plan No. 1: Trash and Bar Removal Required - Cuyahoga River (river mile 13.8 to 40.25)

Trash Removal			
Location of Trash Buildup (by river mile)	Existing Length of Trash Buildup (Feet)	Existing Width of Trash Buildup (Feet)	Trash Removal Required 1/ (Acres)
31.5	1,200	25	0.7
32.5	700	25	0.4
Total	1,900		1.1

Bar Removal			
Location of Bedload Bar Buildup (by river mile)	Existing Length of Bar Buildup (Feet)	Existing Cross Sectional Area of Bar Buildup (Sq. Ft.)	Bar Removal Required 2/ (CY)
19.6	500	200	3,700
26.2	1,000	54	2,000
Total	1,500		5,704

1/ Trash removal required = length of trash buildup X width of trash buildup.
2/ Bar removal required = existing length of bar buildup X existing cross-sectional area of bar buildup.

Table C2.4 - Alternative Plan No. 1: Bank Reconstruction Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

West Bank				East Bank			
River Mile	Length Req'd (Ft)	Height Req'd (Ft)	Bank Reconstruction Required 1/ (CY)	River Mile	Length Req'd (Ft)	Height Req'd (Ft)	Bank Reconstruction Required 1/ (CY)
15.5	500	5	1,851	24.3	800	5	2,963
16.2	900	4	2,400				
24.4	300	4	800				
25.2	300	4	800				
25.3	300	4	800				
25.7	400	4	1,067				
Total	2,700		7,718		800		2,963

1/ Quantity calculated using typical cross-section shown on Figure C2.5 X length required.

(b) Tributaries Studied to the USGS Sediment Gage (Chippewa Creek, Furnace Run, Yellow Creek, and Mud Brook - Of the 5.7 miles of streambanks studied for this report (30,200 feet), 1.7 miles (9,100 feet), or 30 percent were identified as actively eroding. Simple treatment was selected to control 0.1 miles (500 feet), or five percent of these eroding banks and armoring treatment was selected for the remaining 1.6 miles (8,600 feet), or 95 percent. The specific locations where each type of treatment method is required are outlined in Tables C2.5 and C2.6.

In addition to the treatment methods outlined above, 0.5 miles of trash and bar removal is required and their specific locations are shown on Table C2.7. Again, the presently eroding streambank will require armoring treatment to prevent future streambank erosion. This armoring treatment has been included in Table C2.6.

Table C2.5 - Alternative Plan No. 1: Simple Treatment Required by Stream Mile - Tributaries Studied to the USGS Sediment Gage

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
	Chippewa Creek (stream mile 0.0 to 0.4)			
0.0 to 0.4	0-1	200	4	0.18
		200		0.18
	Furnace Run (stream mile 0.0 to 1.5)			
0.0 to 1.5		None		None
	Yellow Creek (stream mile 0.0 to 0.8)			
0.0 to 0.8		None		None
	Mud Brook (stream mile 0.0 to 0.2)			
0.0 to 0.2	0-6	300	5	0.03
		300		0.03
Total		500		0.21

1/ Simple treatment = length required X average bank height.

Table C2.6 - Alternative Plan No. 1: Armoring Treatment Required by Stream Mile - Tributaries Studied to USGS Sediment Gage

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
		Chippewa Creek (stream mile 0.0 to 0.4)			
0.0 to 0.4		None			None
		Furnace Run (stream mile 0.0 to 1.5)			
0.0 to 1.5	0-1	200	10	394	104
	0-2	200	8	346	88
	0-3	500	7	805	200
	0-4	700	5	959	224
	0-5	1,000	7	1,610	400
	0-6	300	6	447	108
	0-7	200	7.5	334	84
	0-8	500	6.5	775	190
	0-9	300	3.5	357	78
	0-10	300	6	447	108
	1-1	200	25	754	224
	1-2	300	7	483	120
	1-3	500	10.5	1,015	270
		5,200		8,726	2,198
		Yellow Creek (stream mile 0.0 to 0.8)			
0.0 to 0.8	0-1	300	5.5	429	102
	0-2	400	9.5	764	200
	0-3	600	7	966	240
	0-4	100	4	125	28

Table C2.6 - Alternative Plan No. 1: Armoring Treatment Required by Stream Mile - Tributaries Studied to USGS Sediment Gage (Cont'd)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	Yellow Creek (Cont'd)				
	0-5	400	17	1,124	320
	0-6	200	50 2/	1,354	424
		2,000		4,762	1,314
	Mud Brook (stream mile 0.0 to 0.2)				
0.0 to 0.2	0-1	200	5	274	64
	0-2	300	6	447	108
	0-3	200	5	274	64
	0-4	200	5	274	64
	0-5	500	8	865	220
		1,400		2,134	520
Total		8,600		15,622	4,032

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambank only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.7 - Alternative Plan No. 1: Trash and Bar Removal Required - Tributaries Studied to USGS Sediment Gage

Trash Removal			
	None Required		

Bar Removal			
Location of Bedload Bar Buildup (by stream mile)	Existing Length of Bar Buildup (feet)	Existing Cross Sectional Area of Bar Buildup (Sq. Ft.)	Bar Removal Required 1/ (CY)
Chippewa Creek (stream mile 0.0 to 0.4)			
	None Required		
Furnace Run (stream mile 0.0 to 1.5)			
0.4	400	50	741
0.6	300	50	556
0.7	500	50	926
0.9	800	50	1,481
	2,000		3,704
Yellow Creek (stream mile 0.0 to 0.8)			
0.3	300	50	556
0.6	400	50	741
	700		1,297
Mud Brook (Stream Mile 0.0 to 0.2)			
	None Required		
Total	2,700		5,001

1/ Bar removal required = existing length of bar buildup X existing cross-sectional area of bar buildup.

(c) <u>Brandywine (Stream Mile 0.0 to 11.6) and Indian Creeks (Stream Mile 0.0 to 3.2)</u> - Of the 29.6 miles of streambanks studied for this report, 2.5 miles, or eight percent, were identified as actively eroding. Simple treatment was selected to control 1.9 miles, or 76 percent of these eroding banks, and armoring treatment was selected for the remaining 0.6 miles, or 24 percent. The specific locations where each type of treatment method is required are shown on Tables C2.8 and C2.9.

(d) <u>Tinkers Creek (Stream Mile 0.0 to 27.3)</u> - Of the 54.6 miles of streambanks studied for this report, 4.1 miles, or eight percent, were identified as actively eroding. Simple treatment was selected to control 0.9 miles, or 22 percent, and armoring treatment was selected for the remaining 3.2 miles, or 78 percent. The specific locations where each type of treatment method is required are shown on Tables C2.10 and C2.11.

The second objective considered in formulating Alternative Plan No. 1 was to prevent future streambank erosion in areas where the present rate of bank erosion (annual lateral recession) is negligible or within tolerable limits. Therefore, management treatment was selected for the remaining 120.3 miles of stable streambanks, or 84 percent of the total streambanks studied for this report. This management treatment program would consist of annual maintenance activities on the existing vegetation cover (which is responsible for the negligible bank erosion along these streambanks) and semi-annual inspections of the streambanks to verify that these banks were still stable. If the existing vegetation cover is disturbed in the future, and unstable banks develop, the appropriate treatment method (simple treatment or armoring treatment) would be identified and implemented.

In conclusion, Alternative Plan No. 1 consists of a plan of action to control the 22.7 miles of actively eroding streambanks and the seven potential meander changes in the study area and a plan of action to insure that future streambank erosion does not occur on the 120.3 miles of presently stable streambanks. A summary of the total required streambank treatment needs is presented in Table C2.12 and is shown on Plates C2-1 to C2-5 in Appendix I.

Table C2.8 - Alternative Plan No. 1: Simple Treatment Required by Stream Mile - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
		Brandywine Creek		
0.0 to 1.0	0-1	1,200	4	0.11
	0-2	200	6	0.03
	0-3	100	5	0.01
	0-4	300	5	0.03
	0-6	1,600	5	0.18
	0-7	300	6	0.04
	0-8	400	6	0.06
	0-9	200	5	0.02
	0-10	200	5	0.02
		4,500		0.50
1.0 to 2.0	1-6	200	3	0.01
		200		0.01
2.0 to 8.0		None		None
8.0 to 9.0	8-1	400	7	0.06
	8-2	400	7	0.06
		800		0.12
9.0 to 10.0	9-1	700	7	0.11
	9-2	700	7	0.11
		1,400		0.22
10.0 to 11.6		None		None

Table C2.8 - Alternative Plan No. 1: Simple Treatment Required by Stream Mile - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively) (Cont'd)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
		Indian Creek		
0.0 to 2.0		None		None
2.0 to 3.0	2-1	1,500	6	0.21
	2-2	1,500	6	0.21
		3,000		0.42
3.0 to 3.2		None		None
Total		9,900		1.27

1/ Simple treatment = length required X average bank height.

Table C2.9 - Alternative Plan No 1: Armoring Treatment Required by Stream Mile - Brandywine and Indian Creeks (stream mile 0.0 to 11.6 and stream mile 0.0 to 3.2, respectively)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
		Brandywine Creek			
0.0 to 1.0	0-5	500	12	1,105	300
	0-11	400	6	596	144
		900		1,701	444
1.0 to 2.0	1-1	200	8	346	88
	1-2	400	30	1,748	528
	1-3	700	11	1,463	392
	1-4	400	7	644	160
	1-5	200	5	274	64
	1-7	300	80 2/	3,183	994
		2,200		7,658	2,226
2.0 to 11.6		None			None
		Indian Creek			
0.0 to 3.2		None			None
Total		3,100		9,359	2,670

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambanks only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.10 - Alternative Plan No. 1: Simple Treatment Required by Stream Mile - Tinkers Creek (stream mile 0.0 to 27.3)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
0.0 to 1.0	0-1	500	9	0.10
	0-2	100	3	0.01
	0-4	400	5.5	0.05
	0-6	400	6	0.06
		1,400		0.22
1.0 to 2.0	1-4	1,000	5	0.11
	1-5	300	5	0.03
		1,300		0.14
2.0 to 14.0		None		None
14.0 to 15.0	14-2	400	5	0.05
	14.2	400	6	0.08
	14.5	300	5	0.03
	14.6	500	5	0.06
		1,800		0.22
15.0 to 27.3		None		None
Total		4,500		0.58

1/ Simple treatment = length required X average bank height.

Table C2.11 - Alternative Plan No. 1: Armoring Treatment Required by Stream Mile - Tinkers Creek (stream mile 0.0 to 27.3)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quanity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
0.0 to 1.0	0-3	700	5	959	224
	0-5	300	5.5	429	102
	0-7	100	6	149	36
	0-8	700	5	959	224
	0-9	2,000	4.8	2,692	624
		3,800		5,188	1,210
1.0 to 2.0	1-1	1,000	5	1,370	520
	1-2	800	5	1,096	256
	1-3	600	4	750	168
	1-6	500	70 2/	4,585	1,460
	1-7	300	4.5	393	90
	1-8	1,100	4	1,375	308
		4,300		9,569	2,802
2.0 to 3.0	2-1	700	12	1,547	420
		700		1,547	420
3.0 to 4.0	3-1	700	4	875	196
		700		875	196
4.0 to 5.0	4-1	500	4	625	220
	4-2	700	4.5	1,484	210
	4-3	400	4.5	524	120
		1,600		2,633	550

Table C2.11 - Alternative Plan No. 1: Armoring Treatment Required by Stream Mile - Tinkers Creek (stream mile 0.0 to 27.3) (Cont'd)

Stream Section (by stream mile)	Eroding Reach: Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quanity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
5.0 to 6.0		None			None
6.0 to 7.0	6-1	100	10	197	172
		100		197	172
7.0 to 11.0	None				
11.0 to 12.0	11-1	2,500	7	4,025	1,000
	11-2	2,500	20	7,925	2,300
		5,000		11,950	3,300
12.0 to 14.0	None				
14.0 to 15.0	14-1	400	5	548	128
	14-3	600	7	966	240
		1,000		1,514	368
15.0 to 27.3	None				
Total		17,200		33,473	9,018

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambanks only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.12 - Alternative Plan No. 1: Summary of Required Streambank Treatment Needs - Total Channel Component Study Area 1/

Treatment Method	Miles of Treatment Required
1. Management Treatment	120.3
2. Simple Treatment	7.2
3. Armoring Treatment	15.5
4. Trash and Bar Removal	1.2
5. Bank Reconstruction	0.7

1/ Cuyahoga River (river mile 13.8 to 40.25), Chippewa Creek (stream mile 0.0 to 0.4), Furnace Run (stream mile 0.0 to 1.5), Yellow Creek (stream mile 0.0 to 0.8), Mud Brook (stream mile 0.0 to 0.2), Brandywine Creek (0.0 to 11.6, including Indian Creek - stream mile 0.0 to 3.2), and Tinkers Creek (stream mile 0.0 to 27.3).

(2) Alternative Plan No. 2 (Critical Area Streambank Stabilization) - Alternative Plan No. 2 was formulated to control the major areas of annual streambank erosion which produce the majority of the sediment load and prevent the formation of the seven potential meander changes along the banks of the Cuyahoga River and the six major tributaries within the channel component study area (see Figure A2.1 in Appendix A). By treating only those major areas of sediment production, this alternative will minimize the cost of construction while still significantly reducing the total sediment load dredged at Cleveland Harbor from streambank erosion.

The results of the studies presented in Appendix A indicated that of the 22.7 miles of actively eroding streambanks, 13.2 miles, or 58 percent, of the eroding streambanks produce the majority of the sediment load derived from annual streambank erosion. These areas are as follows:

(1)	Cuyahoga River:	river mile 13.8 to 15.1
		river mile 18.0 to 20.0
		river mile 22.0 to 25.0
		river mile 26.0 to 27.0
		river mile 30.0 to 33.0
(2)	Furnace Run:	stream mile 0.0 to 1.5
(3)	Yellow Creek:	stream mile 0.0 to 0.8
(4)	Brandywine Creek:	stream mile 1.0 to 2.0
(5)	Tinkers Creek:	stream mile 1.0 to 2.0
		stream mile 11.0 to 12.0

These areas produce 44,000 cubic yards of sediment per year or 85 percent of the total volume from annual streambank erosion. The studies also indicated that there were seven locations on the Cuyahoga River (river mile 23.3, 25.3, 25.7, 26.1, 34.8(a), 34.8(b), and 39.0) where the existing high rate of annual streambank erosion (annual lateral recession) was likely to produce a change in the course of the river (potential meander change). If these potential meander changes were to occur, they would introduce an additional 125,000 cubic yards of sediment into the river system (see Table A2.24). The only objective considered in formulating Alternative Plan No. 2 was therefore to control the 13.2 miles of eroding streambanks which produce the majority of the sediment load from annual streambank erosion (85 percent) and to prevent the formation of the seven potential meander changes and their resultant sediment load.

The results of the studies presented in Appendix A also indicated that there were several sites where damage to local roads and railroad facilities of the Baltimore and Ohio Railroad would occur in the future because of the high rates of annual lateral recession at these locations. Local roads that are endangered occur at river mile 24.6 and 35.0 on the Cuyahoga River. Railroad facilities that are endangered occur at river mile 14.8 and 26.2 on the Cuyahoga River, stream mile 0.4 on Furnace Run, and stream mile 0.2 on Yellow Creek. By controlling streambank erosion at these sites, damage to the local roads and railroad facilities will also be prevented.

The plan that was formulated to control the 13.2 miles of eroding streambanks and the seven potential meander changes consisted of the same treatment methods specified for Alternative Plan No. 1 in the areas identified above. For example, between river mile 13.8 to 15.1 on the Cuyahoga River the same treatment methods specified for Alternative Plan No. 1 to control the eroding streambanks were specified for Alternative Plan No. 2. Conversely, between river mile 15.1 to 16.0 no streambank protection was included in Alternative Plan No. 2 since these areas did not produce a significant sediment load. In addition, armoring treatment was included in Alternative Plan No. 2 to prevent the formation of the seven potential meander changes. The specific locations where each treatment method was selected is discussed below by stream.

(a) <u>Cuyahoga River (River Mile 13.8 to 40.25)</u> - Of the 14.4 miles of actively eroding streambanks along the Cuyahoga River, 9.4 miles, or 65 percent will be protected in Alternative Plan No. 2. Simple treatment was selected to control 2.6 miles, or 28 percent of the eroding streambanks protected in this alternative, and armoring treatment was selected for the remaining 6.8 miles or 72 percent. In addition, 0.6 miles of armoring treatment was included in Alternative Plan No. 2 to prevent the formation of the four potential meander changes located outside the major sediment production areas of annual streambank erosion. The specific locations where each type of treatment method is required are shown on Tables C2.13 and C2.14. These tables also present the estimated quantity of each treatment method that would be required at each specified location. These quantities will be used in the next section in determining the first cost of construction for Alternative Plan No. 2.

In addition to the treatment methods outlined above, 0.6 miles of trash and bar removal and 0.3 miles of bank reconstruction were included in Alternative Plan No. 2 on the Cuyahoga River. Trash and bedload bar buildup was identified as a contributing factor to the high rates of annual lateral recession at several locations. Its removal will therefore aid in protecting the eroding streambanks. The specific locations where trash and bar removal is required are shown on Table C2.15. It should be noted that the presently eroding streambanks will still require armoring treatment to prevent future streambank erosion. This armoring treatment has been included in Table C2.14.

Bank reconstruction is required for Alternative Plan No. 2 at the locations shown on Table C2.16. While the main purpose of bank reconstruction for Alternative Plan No. 1 was to prevent overbank flow and resultant flood plain scour, the main purpose of bank reconstruction for Alternative Plan No. 2 is to provide a stable foundation for the armoring treatment specified at these locations. Armoring treatment will prevent existing annual streambank erosion at river mile 24.3 on the east bank and will prevent the formation of potential meander changes at river mile 25.3 and 25.7 on the west bank. All other areas where bank reconstruction was specified for Alternative Plan No. 1 were not included in Alternative Plan No. 2 because of either of the following: (1) they were outside the specified limits of Alternative Plan No. 2; or (2) the existing streambank presently was not eroding.

In conclusion, the required streambank treatment needs for Alternative Plan No. 2 on the Cuyahoga River includes 2.6 miles of simple treatment, 7.4 miles of armoring treatment (including 0.6 miles to prevent the formation of the four potential meander changes located outside the major sediment production areas of annual streambank erosion), 0.6 miles of trash and bar removal, and 0.3 miles of bank reconstruction.

(b) Tributaries Studied to the USGS Sediment Gage (Chippewa Creek, Furnace Run, Yellow Creek, and Mud Brook) - Of the 1.7 miles of actively eroding streambanks identified in this report 1.4 miles, or 82 percent, will be protected in Alternative Plan No. 2. Simple treatment was not selected to control any of these eroding streambanks since the estimated rate of annual lateral recession at each location was greater than 0.4 feet per year. Armoring treatment was therefore selected to control all 1.4 miles of eroding banks. The specific locations where armoring treatment is required are shown on Table C2.17.

In addition to the 1.4 miles of armoring treatment, 0.5 miles of trash and bar removal is required and their specific locations are shown on Table C2.18. Again, the presently eroding streambank will require armoring treatment to prevent future streambank erosion. This armoring treatment has been included in Table C2.17.

(c) Brandywine (Stream Mile 0.0 to 11.6) and Indian Creeks (Stream Mile 0.0 to 3.2) - Of the 2.5 miles of actively eroding streambanks identified in this report, 0.5 miles, or 20 percent, will be protected in Alternative Plan No. 2. Simple treatment was selected to control 200 feet, or eight percent of the eroding streambanks protected in this alternative, and armoring treatment was selected for the remaining 2,200 feet, or 92 percent. The specific locations where each type of treatment method is required are shown on Tables C2.19 and C2.20.

(d) Tinkers Creek (Stream Mile 0.0 to 27.3) - Of the 4.1 miles of actively eroding streambanks identified in this report, 2.0 miles, or 49 percent, will be protected in Alternative Plan No. 2. Simple treatment was selected to control 0.2 miles, or 12 percent of the actively eroding streambanks protected in this alternative, and armoring treatment was selected to control the remaining 1.8 miles, or 88 percent. The specific locations where each type of treatment method is required are shown on Tables C2.21 and C2.22.

In conclusion, of the 22.7 miles of actively eroding streambanks identified in this report 13.8 miles, or 61 percent, will be protected in Alternative Plan No. 2. A summary of the total required streambank treatment needs is presented in Table C2.23 and is shown on Plates C2-6 to C2-10 in Appendix I.

It should be noted that Alternative Plan No. 2 does not include a provision for inspecting nor implementing future protective measures for the 120.3 miles of presently stable streambanks and the 8.9 miles of eroding streambanks that will not be protected in this scheme. Therefore, if a significant increase in streambank erosion occurs within these areas it will not be detected until it causes an immediate problem to local interests. If this situation occurs

Table C2.13 - Alternative Plan No. 2: Simple Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acres)
13.8 to 15.1		None		None
18.0 to 20.0	18-2	900	8	0.17
		900		0.17
22.0 to 25.0	22-2	2,700	8	0.50
	22-6	2,000	8	0.34
	23-1	1,300	8	0.24
	23-3	900	7	0.14
	23-4	600	6	0.08
	23-7	1,300	6.5	0.20
	23-12	500	8	0.10
	24-2	900	7	0.14
		10,200		1.74
26.0 to 27.0		None		None
30.0 to 33.0	32-3	800	4.5	0.08
	32-5	600	5	0.07
	32-8	800	5	0.10
	32-9	600	5	0.07
		2,800		0.32
Total		13,900		2.23

1/ Simple treatment required = length required X bank height.

Table C2.14 - Alternative Plan No. 2: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
13.8 to 15.1	14-1	500	11	1,045	280
	14-2	1,000	9	1,850	480
	14-3	800	10	2,192	416
	14-4	1,000	9	1,850	480
		3,300		6,937	1,656
18.0 to 20.0	18-1	1,400	9	2,590	672
	18-3	500	9	1,310	240
	18-4	500	10	985	260
	18-5	600	9	1,110	288
	19-1	600	18	1,758	504
	19-2	1,200	14	2,940	816
	19-3	900	13	2,097	576
		5,700		12,790	3,356
22.0 to 25.0	22-1	600	4	750	168
	22-3	1,300	8	2,249	572
	22-4	500	8	865	220
	22-5	700	8	1,211	308
	22-7	1,300	8	2,249	572
	23-2	500	9	1,310	240
	23-5	600	8	1,038	264
	23-6	300	8	519	132

Table C2.14 - Alternative Plan No. 2: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	23-8	1,800	8	3,114	792
	23-9	900	7	1,449	360
	23-10	600	7	966	240
	23-11	600	8	1,038	264
	23-13	1,100	10	2,167	572
	24-1	800	7 2/	1,288	320
	24-3	900	8	1,557	396
		12,500		21,770	5,420
____	25-3 3/	1,000	8 4/	1,394	328
____	25-4 3/	1,200	8 4/	1,692	400
		2,200		3,086	728
26.0 to 27.0	26-1	300	8	519	132
	26-2	1,000	8	1,730	440
	26-3	300	30	1,311	396
	26-4	300	5	411	96
	26-5	600	8	1,038	264
		2,500		5,009	1,328
30.0 to 33.0	30-1	1,100	6	1,639	396
	30-2	600	5.5	858	204
	30-3	600	4.5	786	180
	30-4	1,400	5	1,918	448

Table C2.14 - Alternative Plan No. 2: Armoring Treatment Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25) (Cont'd)

River Section (by river mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	31-1	900	6	1,341	324
	31-2	1,200	5.5	1,716	408
	31-3	1,700	6.3	2,594	632
	31-4	600	4.5	786	180
	32-1	400	7.5	668	168
	32-2	1,500	5	2,055	480
	32-4	500	17	1,405	400
	32-6	300	8	519	132
	32-7	700	3.5	[illegible]33	182
		11,500		17,118	4,134
____	34-2 3/	500	9	1,310	240
____	35-1 3/	300	7	483	120
____	39-3 3/	400	8	692	176
		1,200		2,485	536
Total		38,900		69,195	17,158

1/ Quantity calculated using typical cross-section shown on Figure C 2.2 X length required.
2/ Includes an additional 5 feet of height to protect face of reconstructed bank.
3/ Riprap required to prevent future meander change in the river.
4/ Includes an additional 4 feet of height to protect face of reconstructed bank.

Table C2.15 - Alternative Plan No. 2: Trash and Bar Removal Required - Cuyahoga River (river mile 13.8 to 40.25)

Trash Removal			
Location of Trash Buildup up river mile	Existing Length of Trash Buildup	Existing Width of Trash Buildup	Trash Removal Required 1/
	(Feet)	(Feet)	(Acres)
31.5	1,200	25	0.7
32.5	700	25	0.4
Total	1,900		1.1

Bar Removal			
Location of Bedload Bar Buildup by river mile	Existing Length of Bar Buildup	Existing Cross-Sectional Area of Bar Buildup	Bar Removal Required 2/
	(Feet)	(Sq. Ft.)	(CY)
19.6	500	200	3,704
26.2	1,000	54	2,000
Total	1,500		5,704

1/ Trash removal required = length of trash buildup X width of trash buildup.
2/ Bar removal required = existing length of bar buildup X existing cross-sectional area of bar buildup.

Table C2.16 - Alternative Plan No. 2: Bank Reconstruction Required by River Mile - Cuyahoga River (river mile 13.8 to 40.25)

West Bank				East Bank			
River Mile	Length Req'd (Feet)	Height Req'd (Feet)	Bank Reconstruction Required 1/ (CY)	River Mile	Length Req'd (Feet)	Height Req'd (Feet)	Bank Reconstruction Required 1/ (CY)
				24.3	800	5	2,963
25.3 2/	300	4	800				
25.7 2/	400	4	1,067				
Total	700		1,867		800		2,963

1/ Quantity calculated using typical cross-section shown on Figure C2.5 X length required.

2/ Bank reconstruction required to prevent future meander change in the river.

Table C2.17 - Alternative Plan No. 2: Armoring Treatment Required by Stream Mile - Tributaries Studied to USGS Sediment Gage

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
	Furnace Run (stream mile 0.0 to 1.5)				
0.0 to 1.5	0-1	200	10	394	104
	0-2	200	8	346	88
	0-3	500	7	805	200
	0-4	700	5	959	224
	0-5	1,000	7	1,610	400
	0-6	300	6	447	108
	0-7	200	7.5	334	84
	0-8	500	6.5	775	190
	0-9	300	3.5	357	78
	0-10	300	6	447	108
	1-1	200	25	754	224
	1-2	300	7	483	120
	1-3	500	10.5	1,015	270
		5,200		8,726	2,198
	Yellow Creek (stream mile 0.0 to 0.8)				
0.0 to 0.8	0-1	300	5.5	429	102
	0-2	400	9.5	764	200
	0-3	600	7	966	240
	0-4	100	4	125	28

Table C2.17 - Alternative Plan No. 2: Armoring Treatment Required by Stream Mile - Tributaries Studied to USGS Sediment Gage (Cont'd)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
		Yellow Creek (Cont'd)			
	0-5	400	17	1,124	320
	0-6	200	50 2/	1,354	424
		2,000		4,762	1,314
Total		7,200		13,488	3,512

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambank only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.18 - Alternative Plan No. 2: Trash and Bar Removal Required - Tributaries Studied to USGS Sediment Gage

Trash Removal

None Required

Bar Removal

Location of Bedload Bar Buildup (by stream mile)	Existing Length of Bar Buildup (Feet)	Existing Cross Sectional Area of Bar Buildup (Feet)	Bar Removal Required 1/ (CY)
Furnace Run (stream mile 0.0 to 1.5)			
0.4	400	50	741
0.6	300	50	556
0.7	500	50	926
0.9	800	50	1,481
	2,000		3,704
Yellow Creek (stream mile 0.0 to 0.8)			
0.3	300	50	556
0.6	400	50	741
	700		1,297
Total	2,700		5,001

1/ Bar removal required = existing length of bar buildup X existing cross-sectional area of bar buildup.

Table C2.19 - Alternative Plan No. 2: Simple Treatment Required by Stream Mile - Brandywine Creek (stream mile 0.0 to 11.6)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required	Average Bank Height	Simple Treatment Required 1/
		(Feet)	(Feet)	(Acre)
1.0 to 2.0	1-6	200	3	.01
Total		200		.01

1/ Simple treatment - length required X average bank height.

Table C2.20 - Alternative Plan No. 2: Armoring Treatment Required by Stream Mile - Brandywine Creek (stream mile 0.0 to 11.6)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required	Average Bank Height	Quantity of Riprap Required 1/	Quantity of Bedding Required 1/
		(Feet)	(Feet)	(CY)	(CY)
1.0 to 2.0	1-1	200	8	346	88
	1-2	400	30	1,748	528
	1-3	700	11	1,463	392
	1-4	400	7	644	160
	1-5	200	5	274	64
	1-7	300	80 2/	3,183	994
Total		2,200		7,658	2,226

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambanks only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.21 - Alternative Plan No. 2: Simple Treatment Required by Stream Mile - Tinkers Creek (stream mile 0.0 to 27.3)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Simple Treatment Required 1/ (Acre)
1.0 to 2.0	1-4	1,000	5	0.11
	1-5	300	5	0.03
		1,300		0.14
11.0 to 12.0		None		None
Total		1,300		0.14

1/ Simple treatment = length required X average bank height.

Table C2.22 - Alternative Plan No. 2: Armoring Treatment Required by Stream Mile - Tinkers Creek (stream mile 0.0 to 27.3)

Stream Section (by stream mile)	Eroding Reach Identification Number	Length Required (Feet)	Average Bank Height (Feet)	Quantity of Riprap Required 1/ (CY)	Quantity of Bedding Required 1/ (CY)
1.0 to 2.0	1-1	1,000	5	1,370	520
	1-2	800	5	1,096	256
	1-3	600	4	750	68
	1-6	500	70 2/	4,585	1,460
	1-7	300	4.5	393	90
	1-8	1,100	4	1,375	308
		4,300		9,569	2,802
11.0 to 12.0	11-1	2,500	7	4,025	1,000
	11-2	2,500	20	7,925	2,300
		5,000		11,950	3,300
Total		9,300		21,519	6,102

1/ Quantity calculated using typical cross-section shown on Figure C2.2 X length required.

2/ Studies in Stage 3 planning will investigate the possibility of armoring the streambanks only up to the 100-year flood stage and protecting the remainder of the slope with simple treatment.

Table C2.23 - Alternative Plan No. 2: Summary of Treatment Required - Total Channel Component Study Area 1/

Treatment Method	Miles of Treatment Required
1. Management Treatment	None
2. Simple Treatment	2.8
3. Armoring Treatment	11.0
4. Trash and Bar Removal	1.2
5. Bank Reconstruction	0.3

1/ Cuyahoga River (river mile 13.8 to 40.25), Chippewa Creek (stream mile 0.0 to 0.4), Furnace Run (stream mile 0.0 to 1.5), Yellow Creek (stream mile 0.0 to 0.8), Mud Brook (stream mile 0.0 to 0.2), Brandywine Creek (0.0 to 11.6, including Indian Creek - stream mile 0.0 to 3.2), and Tinkers Creek (stream mile 0.0 to 27.3).

local interests are advised to contact the Corps of Engineers for technical assistance.

d. COST ESTIMATES FOR ALTERNATIVE PLANS NO. 1 AND NO. 2 - The purpose of this section is to present information to assist in review of the estimate of cost for Alternative Plans No. 1 and No. 2. The section presents information on the estimate of first cost of construction and annual operation and maintenance costs and the estimate of annual charges.

(1) Estimate of First Cost of Construction and Annual Operation and Maintenance Cost - The estimated first cost for Alternative Plans No. 1 and No. 2 are shown on Tables C2.24 and C2.25. Unit prices are based on SCS experience with similar type projects, updated to November 1979 price levels. Quantities estimated in these tables were developed from the information presented in the previous section. In addition, the cost for obtaining a 25-foot wide maintenance and construction easement on lands outside the boundaries of the Cuyahoga Valley National Recreation Area (CVNRA) has been included. It is assumed that lands within the CVNRA would be provided free of charge.

The annual operation and maintenance costs associated with each alternative is also shown in Tables C2.24 and C2.25. These costs are based on a percentage of the estimated first cost of construction and reflect SCS experience with similar type work.

(2) Estimate of Annual Charges - The estimated total project costs and annual charges for Alternative Plans No. 1 and No. 2 are presented in Tables C2.26 and C2.27. It is assumed that construction would require two construction seasons, therefore interest during construction has not been included. The interest and amortization rates used are 7-1/8 percent in accordance with the Water Resources Council Regulation. The economic life of the project is assumed to be 50 years.

Tables C2.26 and C2.27 also provide a breakdown of Federal and non-Federal cost sharing. As discussed in Section C of the Main Report it is assumed that local interests would be required to: (1) furnish all lands and easements required by the project; and (2) maintain the completed project.

Table C2.24 - Alternative Plan No. 1: Estimate of First Cost of Construction and Annual Operation and Maintenance Cost 1/

Treatment Method	Unit	Unit Cost 2/	Quantity	Installation Cost	Annual O&M (% of Installation Cost)	Annual O&M Cost
		$		$		$
1. Lands 3/	Acre	3,000	135	405,000	None	0
2. Management Treatment 4/	Acre	-	116.6	0	450/acre	52,470
3. Simple Treatment						
a. Clearing	Acre	1,700	6.2	10,540	None	0
b. Bank shaping 5/	CY	1.75	19,000	33,250	2	665
c. Seeding & mulch	Acre	1,100	6.2	6,820	3	205
d. Tree planting	Acre	150	6.2	930	1	9
				51,540		
				say 52,000		
4. Armoring Treatment						
a. Clearing	Acre	1,700	16.6	28,220	None	0
b. Bank shaping 5/	CY	1.75	41,050	71,838	2	1,437
c. Slope protection						
(1) Riprap	CY	30	151,937	4,558,110	2	91,162
(2) Bedding	CY	15	39,020	585,300	2	11,706
d. Tree planting	Acre	750	16.6	12,450	1	125
				5,255,918		
				say 5,256,000		
5. Trash & Bar Removal						
a. Trash removal	Acre	1,700	1.1	1,870	5	94
b. Bar removal	CY	5.35	10,705	57,272	3	1,718
				59,142		
				say 59,000		

Table C2.24 - Alternative Plan No. 1: Estimate of First Cost of Construction and Annual Operation and Maintenance Cost 1/ (Cont'd)

Treatment Method	Unit	Unit Cost 2/	Quantity	Installation Cost	Annual O&M (% of Installation Cost)	Annual O&M Cost
		$		$		$
6. Bank Reconstruction						
a. Clearing 6/	Acre	1,700	2.0	3,400	None	0
b. Stripping 7/	CY	2.00	1,620	3,240	2	65
c. Bank reconstruction	CY	2.50	10,681	26,703	1	267
d. Seeding & mulch 8/	Acre	1,100	0.1	110	3	3
				33,443		
				say 33,000		
7. Contingencies (20%)	L.S.	-	-	1,161,000	-	-
Subtotal				6,966,000		159,926
AE&D (17%)				1,184,000		-
S&A (12%)				836,000		-
Total				8,986,000		159,926
				say 9,000,000		say 160,000

1/ November 1979 price levels.
2/ Based on SCS experience with similar type projects.
3/ Preliminary estimate of the cost of obtaining a 25-foot wide maintenance and construction easement on lands outside the boundaries of the Cuyahoga Valley National Recreation Area.
4/ 120.3 miles of streambanks X 8-foot average bank height.
5/ Bank shaping = 0.5 cubic yards per foot X length required.
6/ Clearing = 25-foot width X length of reconstructed bank.
7/ Stripping = 25-foot width X length of reconstructed bank X .5-foot depth.
8/ Seeding and mulching to protect face of reconstructed bank at Cuyahoga River miles 15.5, 24.4, and 25.2. (All other reconstructed banks will be protected by armoring and has been included in Item 4.)

Table C2.25 - Alternative Plan No. 2: Estimate of First Cost of Construction and Annual Operation and Maintenance Cost 1/

Treatment Method	Unit	Unit Cost 2/	Quantity	Installation Cost	Annual O&M (% of Installation Cost)	Annual O&M Cost
		$		$		$
1. Lands 3/	Acre	3,000	14	42,000	None	0
2. Management Treatment	Acre	-	None	0	$450/acre	0
3. Simple Treatment						
a. Clearing	Acre	1,700	2.38	4,046	None	0
b. Bank shaping 4/	CY	1.75	7,700	13,475	2	270
c. Seeding & mulch	Acre	1,100	2.38	2,619	3	79
d. Tree planting	Acre	150	2.38	357	1	4
				20,497		
				say 20,000		
4. Armoring Treatment						
a. Clearing	Acre	1,700	12.15	20,655	None	0
b. Bank shaping 4/	CY	1.75	28,800	50,400	2	1,008
c. Slope Protection						
(1) Riprap	CY	30	111,860	3,355,800	2	67,116
(2) Bedding	CY	15	28,998	434,970	2	8,699
d. Tree planting	Acre	750	12.15	9,113	1	91
				3,870,938		
				say 3,871,000		
5. Trash and Bar Removal						
a. Trash removal	Acre	1,700	1.1	1,870	5	94
b. Bar removal	CY	5.35	10,705	57,272	3	1,718
				59,142		
				say 59,000		

Table C2.25 - Alternative Plan No. 2: Estimate of First Cost of Construction and Annual Operation and Maintenance Cost 1/ (Cont'd)

Treatment Method	Unit	Unit Cost 2/	Quantity	Installation Cost	Annual O&M (% of Installation Cost)	Annual O&M Cost
		$		$		$
6. Bank Reconstruction						
a. Clearing 5/	Acre	1,700	0.9	1,530	None	0
b. Stripping 6/	CY	2.00	694	1,388	2	28
c. Bank reconstruction	CY	2.50	4,830	12,075	1	121
d. Seed & mulch	Acre	1,100	None	0	3	0
				14,993		
				say 15,000		
7. Contingencies (20%)	L.S.	-	-	801,000	-	-
Subtotal				4,808,000		79,228
AE&D (17%)				817,000		-
S&A (12%)				577,000		-
Total				6,202,000		79,228
						say 79,000

1/ November 1979 price levels.
2/ Based on SCS experience with similar type projects.
3/ Preliminary estimate of the cost of obtaining a 25-foot wide maintenance and construction easement on lands outside the boundaries of the Cuyahoga Valley National Recreation Area.
4/ Bank shaping = 0.5 cubic yards per foot X length required.
5/ Clearing = 25-foot width X length of reconstructed bank.
6/ Stripping = 25-foot width X length of reconstructed bank X .5-foot depth.

Table C2.26 - Alternative Plan No. 1: Estimate of Annual Charges 1/

Item	Federal	Non-Federal	Total
	$	$	$
First Cost	8,581,000	405,000	8,986,000
Interest During Construction	0	0	0
Total Project Costs	8,581,000	405,000	8,986,000
Annual Charges			
Interest	611,400	28,900	640,300
Amortization	20,300	1,000	21,300
Maintenance	0	160,000	160,000
Total	631,700	189,900	821,600

1/ Based on November 1979 price levels, 7-1/8 percent interest rate and a 50-year economic life.

Table C2.27 - Alternative Plan No. 2: Estimate of Annual Charges 1/

Item	Federal	Non-Federal	Total
	$	$	$
First Cost	6,160,000	42,000	6,202,000
Interest During Construction	0	0	0
Total Project Costs	6,160,000	42,000	6,202,000
Annual Charges			
Interest	438,900	3,000	441,900
Amortization	14,500	100	14,600
Maintenance	0	79,000	79,000
Total	453,400	82,100	535,500

1/ Based on November 1979 price levels, 7-1/8 percent interest rate and a 50-year economic life.

C3. UPLAND WATERSHED COMPONENT

a. GENERAL - The purpose of this section is to present a series of management programs that would be required to reduce the erosion that is occurring in the upland watershed component study area. As previously defined, the upland watershed component study area consists of the 303 square-mile drainage area of the Cuyahoga River between Independence (river mile 13.8) and Old Portage (river mile 40.25) (see Figure A1.1 in Appendix A). Sources of sediment from the upland area have been previously identified and quantified in Appendix A and were shown to contribute the predominant portion of the sediment load being transported by the Cuyahoga River to Cleveland Harbor.

The management programs discussed in this section are not site specific, i.e., the information presented herein will not enable the reviewer to identify a specific location and select a particular type of treatment that would be appropriate for erosion control at that location. They were developed to inform local interests of the types and extent of treatment measures that would be required to control erosion in the upland area and the magnitude of the costs which would be involved. As the management programs are implemented, they will require modifications to conform to specific field conditions. It will be the responsibility of the local interests implementing the program to identify the specific designs required for each individual site.

As discussed in Appendix A, sources of sediment derived from erosion of the upland area were divided into two source types for this report: (1) sediment produced from diffuse nonpoint sources (sheet and rill erosion); and (2) sediment produced from identifiable nonpoint sources (gully erosion on disturbed areas). Separate management programs will, therefore, be presented to correspond to these separate source types.

b. ROLE OF THE CORPS OF ENGINEERS IN UPLAND EROSION CONTROL - As discussed in Section B of the Main Report - "Problem Identification," Corps of Engineers policy prohibits active participation in improvements on privately-owned land (in this instance, the Cuyahoga Valley National Recreation Area is classified as privately-owned land). Therefore, the Corps of Engineers will not implement (construct) the management programs presented in this section for controlling erosion in the upland area. Rather, the Corps will look to other units of Government, such as the National Park Service, the Soil and Water Conservation Districts, State, county, and city governments, other local agencies and to individual landowners to implement the management programs.

The Corps views its role as a planning agency and a catalyst. In its role as a planning agency, its goals are to quantify the upland erosion problem, identify the critically eroding areas, and identify techniques that could be implemented by others to reduce erosion of the land surface. In this capacity, the Corps has entered into an Interagency Agreement with the U. S. Soil Conservation Service because of their expertise in these areas. In its role as a catalyst, its goals are to stimulate an awareness in the watershed area as to erosion problems that exist and the possible measures that can be

implemented to control it. These goals have been partially met with the preparation and dissemination of this Preliminary Feasibility Report and will be culminated with the preparation of the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

c. <u>GENERAL DESIGN CONSIDERATIONS</u> - The management programs presented in this appendix consist of various combinations of Best Management Practices (BMP's) as detailed in the SCS "Technical Guide" and a publication entitled "Water Management and Sediment Control for Urbanizing Areas" SCS, Columbus, OH, (June 1978). BMP's are defined for this report as those practices that will prevent or reduce the sediment load generated from diffuse and identifiable nonpoint sources of erosion. They need only be implemented, however, on those areas which presently have a critical erosion problem (16 percent of the total study area).

The BMP's recommended in this study were selected because of their ability to provide erosion control. They have been thoroughly tested in various Agricultural Research Stations and by farmers and landowners in actual field use. In addition, local Soil and Water Conservation Districts have periodically conducted field days in their counties, demonstrating the implementation of these BMP's and their effectiveness in erosion control. These field days have stimulated landowners to implement these BMP's which has further established their reliability in effective erosion control.

The BMP's recommended in this study can be grouped into three categories: (1) BMP's that improve the existing ground cover; (2) BMP's that reduce the overland flow velocity of surface runoff; and (3) BMP's that lessen the impact of sediment produced by erosion on downstream areas. These three categories are discussed below.

(1) <u>BMP's That Improve The Existing Ground Cover</u> - Ground cover provides erosion protection in the following ways. The ground cover acts as a cushion which absorbs the impact energy of the raindrop before it comes in contact with the soil surface. Ground cover also protects the soil surface from the erosive force of the resultant runoff in the following ways: (1) it acts as a shield which prevents direct contact between the soil surface and the overland flow; (2) it provides increased resistance to overland flow which decreases its flow velocity and resultant erosive force; and (3) it acts as a sponge, absorbing and storing a portion of the rainfall and thus reducing the total amount of runoff produced. In addition, the root system developed by the ground cover tends to hold the soil particles together.

The BMP's that improve the existing ground cover were found to be the most cost-effective means of controlling sheet and rill erosion (diffuse nonpoint sources) in the study area, although other types of BMP's were also required in isolated locations. The BMP's selected for use are as follows:

<u>Critical Area Stabilization (Temporary or Permanent Vegetation)</u>. Stabilization of eroding areas is accomplished by establishing temporary vegetation (wheat, oats, rye, annual grasses, etc.) or permanent vegetation (perennial grasses, shrubs, vines, etc.). As previously discussed, this

vegetation covering acts as a buffer, protecting the soil surface from the erosive force of the raindrop and resultant runoff. Temporary vegetation is applicable to construction sites and other sites that will have bare soil for a short period of time. Permanent vegetation is applicable to any land use encountered in the study area and was the principal erosion control technique selected for use. Typical cost for this BMP is approximately $300 per acre, including site preparation, seeding, fertilizing, and mulching.

Conservation Cropping System. The purpose of this BMP is to protect cropland during periods when the cash crop does not afford adequate protection (immediately after planting or harvesting) or when the field lays fallow. It involves management measures such as no tillage (which leaves a protective plant residue on the soil surface), minimum tillage (which reduces the amount of runoff and resultant sheet erosion because the soil is able to absorb more of the rainfall), and planting of temporary cover such as rye or annual grasses to estblish a protective cover during periods when no cash crops are grown. This BMP does not involve any additional cost to the farmer and will generally increase his crop yield and thus his profit. This BMP has limited use in the study area, however, because of the limited amount of cropland present in the basin.

Pasture and Hayland Planting. This BMP involves reestablishing pasture and hayland species (legumes and grasses) which die out due to natural and man-made causes (winter kill, overgrazing, disease, etc.). This BMP has an average cost of $22 per acre.

Heavy Use Area Protection. This BMP involves protecting the ground surface in heavy use areas such as recreation land and commercial-industrial land. The type of area and the use to which it is put will determine the type of covering needed, such as concrete, asphalt, gravel, sawdust, woodchips, etc. The cost of this BMP varies depending on the type of cover selected. For this report, it is assumed that the cost is approximately $400 per acre.

Woodland Site Preparation. The purpose of this BMP is to prepare an existing woodland area for new tree planting (the next BMP discussed). It involves killing in place or harvesting the existing tree species in order that the newly planted tree species have adequate sunlight and space. The cost of this BMP is $50 per acre.

Tree Planting. This BMP involves planting tree species, such as oak, hemlock, or white pine, which have slow decaying litter duff and which promote the establishment of an understory canopy. As discussed in Appendix A, it was apparent that the absence of a litter duff layer and a understory canopy was the major contributing factor to the high erosion rates on steep, forested slopes. This condition existed when the dominant forest species were maple, ash, and tulip-poplar. A species composition change to oak, hemlock, or white pine will, therefore, retard and/or prevent further sheet erosion. Field conditions confirmed that little or no sheet erosion exists when the dominant forest species are oak, hemlock, or white pine. The cost of this BMP is approximately $150 per acre.

Woodland Improvement. This BMP involves selective thinning of maple, ash, and tulip-poplar species from an existing forest to allow sunlight to penetrate to the forest floor. This will encourage growth of preferred tree species such as oak, hemlock, and white pine which presently exist in the area as seedlings. If the existing forest is not thinned out, these seedlings will eventually die. The cost of this BMP is $40 per acre.

(2) BMP's That Reduce Overland Flow Velocity - The erosive force of overland flow is proportional to its flow velocity, increasing as the flow velocity increases. This situation becomes critical in areas with steep slopes and long slope lengths where overland runoff approaches its maximum flow velocity. Therefore, by reducing the flow velocity of overland runoff in these areas, a reduction in erosion will result.

The BMP's that reduce overland flow velocity have limited use in controlling sheet and rill erosion (diffuse nonpoint sources) in the study area. They are, however, the most cost-effective means of controlling gully erosion (identifiable nonpoint sources of erosion), although other types of BMP's, particularly critical area stabilization, are also required. The BMP's selected for use are as follows:

Runoff Diversion (Temporary or Permanent). This BMP consists of constructing a lateral ditch or channel across the face of the slope to reduce the slope length and thus the flow velocity of overland flow. In addition to reducing overland flow velocity, this BMP also reduces the amount of runoff on areas on the downslope side of the new channel. Implementation of this BMP is applicable to residential and commercial-industrial land currently under construction where little or no protective vegetative covering is present and to all identifiable nonpoint sources of erosion. Safe disposal of the collected runoff will be provided by either a grassed waterway (the next BMP discussed) or discharging into an existing drainage channel. The cost of this BMP is approximately $2.00 per linear foot, including the cost of seeding the new channel.

Grassed Waterway. This BMP consists of constructing a waterway that follows the slope of the land in order to provide a means of safe disposal of collected runoff water to a receiving stream. This BMP will be used in combination with runoff diversions or in cropland to dispose of runoff collected by crop rows. The cost of this BMP is approximately $500 per acre. For example, a grassed waterway 800-feet long and 25-feet wide would cost $230.

Grade Stabilization Structure - This BMP consists of a structure, such as a stone flume or concrete drop structure, to stabilize the outlet of a natural channel or grassed waterway and prevent head cutting. This BMP will be used in combination with grassed waterways, as required, to dispose of collected runoff water into a receiving stream. The cost of this BMP is $2,000 per unit.

(3) BMP's That Lessen the Impact of Sediment Produced by Erosion on Downstream Areas - There are certain areas in the basin (construction sites, gravel pits, and landfills) where erosion control practices cannot be implemented due to the nature or use of the site (continuous land disturbance).

Therefore, in order to lessen the impact of sediment produced by erosion on downstream areas, sediment (debris) basins were selected as the most effective BMP. A sediment (debris) basin collects sediment-laden runoff and is of sufficient size to allow the sediment to settle out before the runoff is discharged to a receiving stream. This BMP is applicable to both identifiable (gully erosion) and diffuse (sheet and rill erosion) nonpoint sources of erosion. Although the cost of this BMP can vary greatly, depending on site conditions, for this study it was assumed to be $1,000 per unit.

Because of the variability in erosion sources, topography, climate, soils, historical use and present land use, no one Best Management Practice will be applicable to all activities or situations. Best Management Practices must be tailored to the needs of the particular site and to the physical conditions that exist. While many of these practices can be implemented by the landowners themselves, landowners are advised to obtain expert assistance from their local Soil and Water Conservation District or private consultants before implementing these BMP's.

d. INSTITUTIONAL ARRANGEMENTS - The Best Management Practices discussed above do not include the institutional arrangements that will be required to supplement the management programs presented in this appendix. These institutional arrangements could be in the form of legislation by regional and/or local units of Government or Memoranda of Understanding between governments and/or agencies at all levels. Legislation could be in the form of ordinances, zoning regulations, and building codes that could cover soil erosion within the jurisdictional boundaries of the instituting unit of government. These laws or legislative measures can be called several different things, but the most common are cut and fill ordinances, erosion control regulations, and water quality or urban storm water management regulations. In fact, many cities have this type of legislation already adopted. It only lacks the enforcement and training of inspectors to do the job. New legislation in Ohio is also now in effect which allows local Soil and Water Conservation Districts (SWCD) and the Ohio Department of Natural Resources to contact individual landowners who have an erosion problem and to initiate erosion control measures. In addition, the Agricultural Conservation Program (ACP), administered through the U. S. Department of Agriculture's Agricultural Stabilization and Conservation Service (ASCS), provides Federal cost-sharing funds to agricultural landowners who implement conservation practices on their land. Since eligibility requirements for participation and the specific conservationpractices that are cost-shared vary from county to county, local interests are advised to contact their local ASCS County Committee for additional details on this program. However, because of the small amount of agricultural land in the study area (less than 10 percent in the five subwatersheds studied for this report), this program will have limited use in controlling upland erosion in the Cuyahoga River Basin.

Memoranda of Understanding are formalized working agreements for mutual assistance between various levels of State, Federal, and local Government. For example, a city may wish to adopt a sediment control ordinance and will request the assistance of the local SWCD. They next agree on a Memorandum of

Understanding which may include such items as limits of each agency's work area, reimbursement procedures, case referral procedures, training of enforcement personnel, enforcement procedures, and who will prepare detailed plans, schedules, and cost estimates.

It is expected that implementation of these institutional arrangements can significantly reduce the erosion problems within the jurisdictional area of the local Governments. In fact, they may well be the most important part of a conservation program in the urbanizing areas of the watershed and should be evaluated before implementing the management programs presented in this appendix.

e. MANAGEMENT PROGRAMS FOR DIFFUSE NONPOINT SOURCES OF EROSION - The upland watershed component study area consists of the 303 square-mile drainage area between Independence, OH, (river mile 13.8) and Old Portage, OH, (river mile 40.25) (see Figure A1.1). The 303 square-mile upland study area was divided into seven subwatersheds for the sheet or diffuse nonpoint source erosion study. These seven subwatersheds are Mud Brook, Brandywine Creek, Tinkers Creek, Chippewa Creek, Furnace Run, Yellow Creek, and the local drainage of the Cuyahoga River. The subwatershed boundaries are shown on Plate A3-1 in Appendix I.

The results or conclusions of the upland erosion study for the five subwatersheds studied (as shown in Tables A3.12 through A3.21) is that 16 percent of the upland area produces 96 percent of the total erosion problem. These two percentages are an average from Tables A3.12 to A3.21 for the five subwatersheds studied for this PFR. The other two subwatersheds of Yellow Creek and Brandywine Creek will be studied in Stage 3 if the recommendation of this report is to continue into Stage 3 planning. The upland critical erosion areas varied from 7 percent to 23 percent of the total area with the critical erosion areas contributing 93 percent to 98 percent of the total sediment load. These upland problem areas (the 16 percent average) can be identified and described from the above-mentioned tables by specific land use and soil type.

The upland potential critical erosion areas are shown on Plates A3-10 through A3-30 in Appendix I using the Ohio Capability Analysis Program (OCAP). These maps were prepared by location of land use and soil type combinations within each subwatershed and the position where these land uses and soil types occur on the landscape. These maps locate all of the potential critical erosion areas. The development of these OCAP maps is discussed in detail in other sections of this report. Through the use of USGS cultural features overlay maps, or county highway maps, a specific potential critical erosion site can be located on the landscape and a route can be identified to reach it for further evaluation and possible treatment.

The separate management programs, as described below and shown in the Tables C3.1 through C3.5 of this appendix, are designed to treat that 16 percent of the upland critical erosion problem area. These separate management programs are groupings of the Best Management Practices (BMP's) needed to correct the critical erosion problem. Each subwatershed management program varies with the type and amount of Best Management Practices needed for specific land

uses, soil types, and the existing vegetative cover conditions interacting to cause the critical erosion problem.

The separate management programs were developed to control critical sheet and rill erosion within five of the seven subwatersheds. The suggested management programs for the remaining two subwatersheds (Brandywine Creek and Yellow Creek) will be completed in Stage 3 if the recommendation of this report is to continue into Stage 3 planning. Following is a discussion of the management programs developed for the Mud Brook, Tinkers Creek, Chippewa Creek, Furnace Run, and local drainage of the Cuyahoga River subwatersheds, and the Summary with General Conclusions.

(1) Mud Brook Subwatershed - Mud Brook has a total drainage area of 29.3 square-miles (18,752 acres) and as shown in Table A3.12 in Appendix A, only about 1,400 acres (approximately seven percent of the total subwatershed area) have been identified as critically eroding. The three predominant land uses in these critical erosion areas are cropland (corn and wheat), woodland and other land. A minor critical land use is wildlife land.

The upland management program for the Mud Brook subwatershed (and also for the remaining subwatersheds) was developed by selecting Best Management Practices (BMP's) for the critically eroding areas of the subwatershed that were actually sampled (the Primary Sample Units - PSU's) and which had an actual soil loss in excess of the tolerable soil loss value (T). This was calculated by the Universal Soil Loss Equation (USLE) and that resulting data put together as shown in Table A3.12 of Appendix A. The individual BMP's required to treat the critical eroding areas were then multiplied by the corresponding subwatershed sampling rate (Table A3.11, Appendix A) to arrive at the total upland recommended management programs shown in Table C3.1. For example, in the Mud Brook subwatershed, with a sampling rate of 20 percent, the quantities of BMP's required to control critical erosion were multiplied by 5 (20 percent) to obtain the total recommended management program shown in Table C3.1.

The recommended management program BMP's are the total of those needed to treat all critical eroding areas for the four land uses shown. No attempt was made to identify specific sites for specific treatment. This will be accomplished at the time of BMP implementation. Only a generalized conclusion was reached in this study as to what BMP's are needed on a specific land use (site) to treat the critical erosion problem. For example, woodland would use tree planting and woodland site preparation, whereas cropland would use a conservation cropping system. Other land would use critical area stabilization and sediment basins. The critical area stabilization BMP would have wide application for the study area.

Mud Brook subwatershed has a total of six BMP's in the recommended management program to treat critical sheet and rill erosion on the four land uses shown in Table A3.12 in Appendix A. Other land (360 acres), and wildlife land (45 acres) for a total of 405 acres, would be treated with critical area stabilization to control critical sheet erosion. In addition, it was projected that 15 sediment basins would be required for other land.

Woodland will be treated for critical sheet erosion with 540 acres of woodland site preparation and tree planting as the recommended BMP's.

It is estimated that 405 acres of cropland would require treatment with conservation cropping system and four acres of grassed waterways would be needed. The grassed waterways are needed to protect natural surface watercourses that receives runoff from crop rows that act as runoff diversion channels.

The total cost to treat the critically eroding areas (seven percent of the total subwatershed) of Mud Brook subwatershed is $325,000. The BMP costs are itemized in Table C3.1.

Table C3.1 - Recommended Management Program for Mud Brook Subwatershed: Estimate of First Cost and Annual Operation and Maintenance Cost

Required Best Management Practices	Unit	Unit Cost[1/]	Quantity[2/]	Initial Installation Cost	Annual O&M % of Installation Cost	Annual O&M Cost
		$		$		$
Critical Area Stabilization	Acres	300	405	121,500	3	3,645
Conservation Cropping System	Acres	0	405	0	0	0
Pasture & Hayland Planting	Acres	50	0	0	1	0
Heavy Use Area Protection	Acres	400	0	0	5	0
Woodland Site Preparation	Acres	50	540	27,000	0	0
Tree Planting	Acres	150	540	81,000	1	810
Woodland Improvement	Acres	40	0	0	0	0
Runoff Diversion	Feet	1	0	0	5	0
Grassed Waterway	Acres	500	4	2,000	3	60
Grade Stabilization Structure	Each	2,000	0	0	5	0
Sediment Basin	Each	1,000	15	15,000	5	750
Contingencies (20%)	L.S.	-	-	49,300	-	-
Subtotal	-	-	-	295,800	-	5,265
Engineering & Design (10%)	-	-	-	29,580	-	-
Total	-	-	-	325,380	0	5,265

1/ Unit costs are based on SCS experience with similar work in the area and are on November 1979 price levels.

2/ The quantities presented are based on a 20 percent ramdom sample of the Mud Brook Subwatershed (see Table A3.8) expanded to the entire subwatershed critical erosion area.

(2) Tinkers Creek Subwatershed - Tinkers Creek has a total drainage area of 85.6 square-miles (54,784 acres) and as shown in Table A3.14 in Appendix A, only about 5,750 acres (approximately 10 percent of the total subwatershed area) have been identified as critically eroding. The four predominant land uses in these critically eroding areas are other land, commercial-industrial land, community services land, and woodland. There are also five minor critical land uses: wildlife land, residential land, cropland, pastureland, and transportation land.

Tinkers Creek subwatershed has a total of eight BMP's in the recommended management program to treat critical sheet and rill erosion for the nine land uses shown in Table A3.14 in Appendix A. Other land (1,030 acres), commercial-industrial land (900 acres), community services land (600 acres), wildlife land (230 acres), residential land (575 acres), and transportation land (115 acres) will be treated for critical sheet and rill erosion with the BMP critical area stabilization. In addition, the BMP's sediment basin (eight), runoff diversion (500 feet), and grassed waterways (one acre) will be recommended for use on commercial-industrial land, community services land and other land where the soil types are cut and fill, made land, and the various man-disturbed soils identified as urban complexes.

Cropland (345 acres) is again treated with the combination of conservation cropping system and grassed waterways (four acres) for critical sheet and rill erosion.

Pastureland (115 acres) will be treated for critical sheet and rill erosion with pastureland and hayland planting.

Woodland will again be treated with 1,495 acres of woodland site preparation and tree planting.

The total initial installation costs to treat the critically eroding areas (10 percent of the total subwatershed) of Tinkers Creek subwatershed is $1,783,000. The BMP costs are shown in Table C3.2.

Table C3.2 - Recommended Management Program for Tinkers Creek Subwatershed: Estimate of First Cost and Annual Operation and Maintenance Cost

Required Best Management Practices	Unit	Unit Cost[1/]	Quantity[2/]	Initial Installation Cost	Annual O&M % of Installation Cost	Annual O&M Cost
		$		$		$
Critical Area Stabilization	Acres	300	3,450	1,035,000	3	31,050
Conservation Cropping System	Acres	0	345	0	0	0
Pasture & Hayland Planting	Acres	50	115	5,750	1	58
Heavy Use Area Protection	Acres	400	-	-	5	-
Woodland Site Preparation	Acres	50	1,495	74,750	0	0
Tree Planting	Acres	150	1,495	224,250	1	2,243
Woodland Improvement	Acres	40	-	-	0	-
Runoff Diversion	Feet	1	500	500	5	25
Grassed Waterway	Acres	500	5	2,500	3	75
Grade Stabilization Structure	Each	2,000	-	-	5	-
Sediment Basin	Each	1,000	8	8,000	5	400
Contingencies (20%)	L.S.	-	-	270,150	-	-
Subtotal	-	-	-	1,620,900		33,851
Engineering & Design (10%)	-	-	-	162,090	-	-
Total	-	-	-	1,782,990	-	33,851

1/ Unit costs are based on SCS experience with similar work in the area and are on November 1979 price levels.

2/ The quantities presented are based on an eight percent ramdom sample of the Tinkers Creek Subwatershed (see Table A3.8) expanded to the entire subwatershed critical erosion area.

(3) Chippewa Creek Subwatershed - Chippewa Creek has a total drainage area of 17.7 square-miles (11,328 acres) and as shown in Table A3.16 in Appendix A, only about 1,800 acres (approximately 16 percent of the total subwatershed area) have been identified as critically eroding. The five predominant land uses in these critically eroding areas are woodland, recreation land, community services land, residential land, and other land. Wildlife land is a minor land use experiencing critical erosion.

The Chippewa Creek subwatershed has a total of seven BMP's in the recommended management program to treat critical sheet and rill erosion on the six land uses shown in Table A3.16 in Appendix A. Recreation land (308 acres), community service land (220 acres), residential land (264 acres), other land (352 acres) and wildlife land (44 acres) will be treated for critical sheet and rill erosion with the BMP critical area stabilization. In addition, the BMP's sediment basins (5), runoff diversions (8,100 feet), and grassed waterways (four acres), are recommended for other land use (44 acres) with the critical soil types of urban land complexes and cut and fills.

Woodland will be treated for critical sheet erosion with 528 acres of the combined BMP's of woodland site preparation and tree planting. Also, 44 acres of woodland will be treated with only the BMP woodland improvement.

The total cost to treat the critically eroding areas (16 percent of the total subwatershed) of the Chippewa Creek subwatershed is $632,095. The BMP costs are itemized as shown in Table C3.3

Table C3.3 - Recommended Management Program for Chippewa Creek Subwatershed: Estimate of First Cost and Annual Operation and Maintenance Cost

Required Best Management Practices	Unit	Unit Cost[1]	Quantity[2]	Initial Installation Cost	Annual O&M % of Installation Cost	Annual O&M Cost
		$		$		$
Critical Area Stabilization	Acres	300	1,188	356,400	3	10,692
Conservation Cropping System	Acres	0	-	0	0	0
Pasture & Hayland Planting	Acres	50	-	-	1	-
Heavy Use Area Protection	Acres	400	-	-	5	-
Woodland Site Preparation	Acres	50	528	26,400	0	0
Tree Planting	Acres	150	528	79,200	1	792
Woodland Improvement	Acres	40	44	1,760	0	0
Runoff Diversion	Feet	1	8,100	8,100	5	405
Grassed Waterway	Acres	500	4	2,000	3	60
Grade Stabilization Structure	Each	2,000	-	-	5	-
Sediment Basin	Each	1,000	5	5,000	5	250
Contingencies (20%)	L.S.	-	-	95,772	-	-
Subtotal	-	-	-	574,632		12,199
Engineering & Design (10%)	-	-	-	57,463	-	-
Total	-	-	-	632,095	-	12,199

1/ Unit costs are based on SCS experience with similar work in the area and are on November 1979 price levels.

2/ The quantities presented are based on a 22 percent ramdom sample of the Chippewa Creek Subwatershed (see Table A3.8) expanded to the entire subwatershed critical erosion area.

(4) <u>Furnace Run Subwatershed</u> - Furnace Run has a total drainage area of 17.7 square-miles (11,328 acres) and as shown in Table A3.18 in Appendix A, only about 2,600 acres (approximately 23 percent of the total subwatershed area) have been identified as critically eroding. The two predominant land uses in these critically eroding areas are woodland and wildlife land. Less predominant land uses experiencing critical erosion are residential land, recreational land, and transportation land.

The Furnace Run subwatershed has a total of three BMP's in the recommended management program to treat critical sheet and rill erosion on the five land uses shown on Table A3.18 in Appendix A. Wildlife land (533 acres), residential land (41 acres), recreational land (41 acres), and transportation land (41 acres) will be treated for critical sheet and rill erosion with the BMP <u>critical area stabilization</u>.

Woodland will be treated for critical sheet erosion on 1,927 acres with the combined BMP's of <u>woodland site preparation</u> and <u>tree planting</u>.

The total cost to treat the critically eroding areas (23 percent of the total subwatershed) of Furnace Run subwatershed is $769,000. The BMP costs for this subwatershed are shown in Table C3.4.

Table C3.4 - Recommended Management Program for Furnace Run Subwatershed: Estimate of First Cost and Annual Operation and Maintenance Cost

Required Best Management Practices	Unit	Unit Cost[1]	Quantity[2]	Initial Installation Cost	Annual O&M % of Installation Cost	Annual O&M Cost
		$		$		$
Critical Area Stabilization	Acres	300	656	196,800	3	5,904
Conservation Cropping System	Acres	0	-	0	0	0
Pasture & Hayland Planting	Acres	50	-	-	1	-
Heavy Use Area Protection	Acres	400	-	-	5	-
Woodland Site Preparation	Acres	50	1,927	96,350	0	0
Tree Planting	Acres	150	1,927	289,050	1	2,891
Woodland Improvement	Acres	40	-	-	0	0
Runoff Diversion	Feet	1	-	-	5	-
Grassed Waterway	Acres	500	-	-	3	-
Grade Stabilization Structure	Each	2,000	-	-	5	-
Sediment Basin	Each	1,000	-	-	5	-
Contingencies (20%)	L.S.	-	-	116,440	-	-
Subtotal	-	-	-	698,640		8,795
Engineering & Design (10%)	-	-	-	69,864	-	-
Total	-	-	-	768,504	-	8,795

1/ Unit costs are based on SCS experience with similar work in the area and are on November 1979 price levels.

2/ The quantities presented are based on a 25 percent ramdom sample of the Furnace Run Subwatershed (see Table A3.8) expanded to the entire subwatershed critical erosion area.

(5) Local Drainage Subwatershed - The local drainage of the Cuyahoga River has a total drainage area of 94.8 square-miles (60,672 acres) and as shown in Table A3.20 in Appendix A, only about 13,000 acres (approximately 21 percent of the total subwatershed area) have been identified as critically eroding. The two predominant land uses in these critically eroding areas are woodland and wildlife land. There are also six additional minor land uses: residential land, other land, commercial-industrial land, recreational land, pastureland, and transportation land experiencing critical erosion.

The local drainage subwatershed has a total of seven BMP's in the recommended management program to treat critical sheet and rill erosion on the eight land uses shown on Table A3.20 in Appendix A. Wildlife land (1,001 acres), residential land (455 acres), other land (182 acres), commercial-industrial land (91 acres), recreational land (91 acres), and transportation land (91 acres) will be treated for critical sheet and rill erosion with the BMP critical area stabilization. In addition, the BMP's diversions (1,100 feet) and grassed waterways are recommended for recreation lands.

Pastureland (91 acres) will be treated for critical sheet and rill erosion with the BMP pasture and hayland planting.

Woodland will again be treated with 10,829 acres of woodland site preparation and tree planting. In addition, the BMP heavy use area protection will be used to treat 91 acres of critical sheet and rill erosion on woodland areas with the soil type Berks silt loam.

The total initial installation cost to treat the critically eroding areas (21 percent of the total subwatershed) of the local drainage of the Cuyahoga River subwatershed is $3,650,000. The BMP costs are shown in Table C3.5.

Table C3.5 - Recommended Management Program for Local Drainage Subwatershed: Estimate of First Cost and Annual Operation and Maintenance Cost

Required Best Management Practices	Unit	Unit Cost[1]	Quantity[2]	Initial Installation Cost	Annual O&M % of Installation Cost	Annual O&M Cost
		$		$		$
Critical Area Stabilization	Acres	300	1,911	573,300	3	17,199
Conservation Cropping System	Acres	0	-	0	0	0
Pasture & Hayland Planting	Acres	50	91	4,550	1	46
Heavy Use Area Protection	Acres	400	91	36,400	5	1,820
Woodland Site Preparation	Acres	50	10,829	541,450	0	0
Tree Planting	Acres	150	10,829	1,624,350	1	16,244
Woodland Improvement	Acres	40	-	-	0	-
Runoff Diversion	Feet	1	1,100	1,100	5	55
Grassed Waterway	Acres	500	1	500	3	15
Grade Stabilization Structure	Each	2,000	-	-	5	-
Sediment Basin	Each	1,000	-	-	5	-
Contingencies (20%)	L.S.	-	-	556,330	-	-
Subtotal	-	-	-	3,337,980		35,379
Engineering & Design (10%)	-	-	-	333,798	-	-
Total	-	-	-	3,671,778	-	35,379

1/ Unit costs are based on SCS experience with similar work in the area and are on November 1979 price levels.

2/ The quantities presented are based on a 10 percent ramdom sample of the Local Drainage Subwatershed (see Table A3.8) expanded to the entire subwatershed critical erosion area.

(6) Summary and General Conclusion - The critical sheet and rill erosion that occurs in the 303 square-mile upland study area between Independence, OH, (river mile 13.8) and Old Portage, OH, (river mile 40.25) as shown in Figure A1.1 in Appendix A, is a major source of the sediment that arrives annually in Cleveland Harbor. Within this area, it has been concluded that 16 percent of the total acreage (24,000 acres) is producing 96 percent of the total sediment dislodged (850,000 tons per year) as shown in Table A3.22 of Appendix A. These critically eroding acres (16 percent) can be successfully treated to reduce erosion to within the tolerable (T) soil loss limits (as shown in Table A3.6 of Appendix A) by implementing management programs (as shown in Tables C3.1 through C3.5 of Appendix C) composed of various combinations of eleven Best Management Practices (BMP's). Three BMP's (critical area stabilization, woodland site preparation, and tree planting) of the eleven are the major ones recommended to control critical sheet and rill erosion in the majority of cases or sites. The total initial installation cost to treat the five subwatersheds studied, is $7,200,000 as shown in Table C3.6 of this appendix or approximately $300 per acre.

The Best Management Practices that are recommended for the upland watershed component have long-term effects on erosion and have relatively low maintenance costs. These BMP's are of a self-liquidating nature with long-term benefits that are equal to or greater than their costs. The BMP's (agronomic, vegetative, and forestry) are simple enough that landowners can implement the practices themselves with very limited technical assistance. This will reduce the installation costs and the landowner can perform the maintenance requirements.

Table C3.6 - Summary of Recommended Management Programs for the Upland Watershed Component Study Area: Estimated First Cost and Annual Operation and Maintenance Cost 1/

Subwatershed 2/	First Cost of Construction	Annual Operation and Maintenance Cost
	$	$
Mud Brook	325,380	5,265
Tinkers Creek	1,782,990	33,851
Chippewa Creek	632,095	12,199
Furnace Run	768,504	8,795
Local Drainage	3,671,778	35,379
Total	7,180,747	95,489
	Say 7,200,000	Say 95,000

1/ Does not include Management Programs for the Brandywine Creek and Yellow Creek Subwatersheds.

2/ Figures apply only to the treatment of identified critical erosion areas as shown in Tables A3.12 through A3.20 in Appendix A.

f. <u>MANAGEMENT PROGRAMS FOR IDENTIFIABLE NONPOINT SOURCES OF EROSION</u> - As outlined in Appendix A, a separate study program was used to identify sediment produced by identifiable nonpoint sources (gully erosion on disturbed areas). Identification of these sources was held close to or within the Standard Project Flood area of the Cuyahoga River. The 36 sites that were identified for this study are shown on Plates A3-31 and A3-32 in Appendix I.

Due to time constraints, management programs to control erosion from identifiable nonpoint sources were not developed for this Preliminary Feasibility Report. Separate management programs, however, will be developed for each identified site during preparation of the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning. These management programs will consist of a combination of several BMP's at each site. For example, the management program for site 27-2 between I-271 and I-80 may possibly consist of the following BMP's: <u>critical area stabilization</u>, <u>runoff diversions</u>, and <u>grassed waterways</u>. These BMP's would function as one unit to control the gully erosion that is occurring at this site.

The management programs that will be developed for each site should be implemented by local interests before any proposed erosion control measures on the streambanks of the Cuyahoga River are implemented by the Corps of Engineers. The success or failure of these proposed streambank protection measures will depend, in part, upon these sites being stabilized due to their proximity to the river.

APPENDIX D

ECONOMIC EVALUATION

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
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ECONOMIC EVALUATION

D1. INTRODUCTION

The purpose of this appendix is to determine the economic efficiency of the alternative plans developed in Appendix C to control streambank erosion and the management programs developed to control erosion of the land surface in the Cuyahoga River Basin between Independence (river mile 13.8) and Old Portage (river mile 40.25) (see Figure A1.1 in Appendix A - Study Area Orientation Map). Economic efficiency will be determined by: (1) estimating the benefits that would be realized from implementation of each erosion control plan on an average annual basis (50-year economic life, 7-1/8 percent interest rate, and November 1979 price levels); and (2) comparing these estimated average annual benefits with the average annual costs of each erosion control plan. (The average annual costs of the erosion control plans were previously estimated in Appendix C).

As discussed in Appendix A, the study area was divided into two study components or individual study areas: (1) the channel component; and (2) the upland watershed component. The economic efficiency of the alternative plans formulated to control streambank erosion in the channel component study area will indicate whether or not further Federal involvement in implementing streambank erosion control plans is warranted and will provide a basis for comparing different alternative plans. It is the policy of the Corps of Engineers not to recommend projects for implementation when the costs of the project exceed the benefits that would be realized (benefit-cost ratio less than 1.0) unless there are overriding considerations of environmental quality, or social impacts warranting a departure from economic (cost-effective) decisions.

The economic efficiency of the management programs developed to control erosion of the land surface in the upland watershed component study area will indicate whether or not it is cost-effective for local interests to implement the developed management programs on their land. (As previously discussed, the Corps will not implement the management programs developed to control erosion in the upland area. Rather, the Corps will look to local interests to implement these programs). In addition, the benefits that would be realized by the Federal Government, as indicated by reduced dredging requirements at Cleveland Harbor, will also be estimated to determine if further Federal involvement in the upland watershed component study area is warranted. This involvement includes, but is not limited to, the following: (1) completing the diffuse nonpoint source erosion study (sheet and rill erosion) in Brandywine Creek and Yellow Creek subwatersheds and developing management programs to control this erosion; and (2) quantifying the identifiable nonpoint sources of erosion (gully erosion on disturbed areas) and developing separate management programs to control this erosion.

The following sections of this appendix will present the results of the studies for each component. Each section will start with a general introduction, followed by an estimate of the benefits that would be realized from implementation of each erosion control plan and a determination of its economic efficiency.

D2. CHANNEL COMPONENT

a. GENERAL - The channel component consists of the main stem of the Cuyahoga River from Independence (river mile 13.8) to Old Portage (river mile 40.25) and the channels of the six major tributaries in this reach. These tributaries are Mud Brook, Brandywine Creek, and Tinkers Creek on the east side of the basin and Yellow Creek, Furnace Run, and Chippewa Creek on the west side of the basin. Two tributaries - Brandywine Creek (including Indian Creek, the major tributary of Brandywine Creek), and Tinkers Creek were studied over their entire length. The remaining four tributaries were only studied from their confluence with the Cuyahoga River upstream to the USGS sediment gaging station on each tributary. The study reaches for the Cuyahoga River and the six major tributaries are shown on Figure A2.1 in Appendix A.

The results of the studies presented in Appendix A indicated that annual streambank erosion produces about 52,000 cubic yards of sediment annually (see Table A2.22 in Appendix A). Of this 52,000 cubic yards of sediment, it is estimated that approximately 47,000 cubic yards is transported by the Cuyahoga River to Cleveland Harbor and requires annual maintenance dredging. This volume of sediment represents about 5 percent of the total volume of maintenance dredging required at Cleveland Harbor. The studies also indicated that there were seven locations on the Cuyahoga River where the existing high rate of annual streambank erosion was likely to produce a future change in the course of the river (potential meander change). In addition, the studies also indicated that there were several sites where damage to local roads and railroad facilities would occur in the future because of the high rates of annual streambank erosion at these locations.

As discussed in Section C of the Main Report - "Formulation of Alternative Plans," preliminary evaluation of possible conceptual solutions indicated that only three alternatives warranted further consideration. These alternatives are: (1) Alternative Plan No. 1 (Total Streambank Stabilization); (2) Alternative Plan No. 2 (Critical Area Streambank Stabilization); and (3) Alternative Plan No. 3 (Settling Basin). In addition, Alternative Plan No. 4 (No-Action (Do-Nothing) Plan) was also carried forward as a basis of comparison of the above structural and nonstructural plans.

Two alternative plans (Alternative Plan No. 1 and Alternative Plan No. 2) were formulated for this report, and their economic efficiency will be determined in the following discussion. Alternative Plan No. 3 (Settling Basin) was originally formulated for the "First Interim Report" of the Cuyahoga River Restoration Study. Additional study on this alternative was limited to reevaluating its feasibility in light of current conditions within the study area. This is described in sufficient detail in Section D of the Main Report - "Assessment and Evaluation of Preliminary Plans."

b. <u>ESTIMATE OF AVERAGE ANNUAL BENEFITS</u> - This section presents an estimate of the average annual benefits that would be realized from implementation of either Alternative Plan No. 1 or Alternative Plan No. 2. Benefit categories that will be investigated include the following: (1) reduced dredging requirements at Cleveland Harbor as a result of controlling annual streambank erosion; (2) reduced dredging requirements at Cleveland Harbor as a result of preventing formation of the seven potential meander changes; (3) land conservation; and (4) flood control.

As discussed in Section B of the Main Report - "Problem Identification," the present method of disposing of the dredged material at Cleveland Harbor is to confine the material in diked disposal sites. It is not known, however, if the U. S. Environmental Protection Agency (EPA) will require diked disposal of dredged material or will permit open-lake disposal after Dike 14 (currently under construction) is filled to capacity (currently estimated to be filled in 1986 or 1987). Therefore, two benefit scenarios will be developed: (1) scenario 1 will assume open-lake disposal of dredged material; and (2) scenario 2 will assume continued diked disposal for the 50-year economic life of the project.

(1) <u>Reduced Dredging Requirements at Cleveland Harbor as a Result of Controlling Annual Streambank Erosion</u> - As previously discussed, it is estimated that annual streambank erosion produces approximately 47,000 cubic yards of sediment that requires annual maintenance dredging at Cleveland Harbor. Alternative Plan No. 1 was formulated to control all existing annual streambank erosion. It is virtually impossible, however, to completely control the total sediment load produced from annual streambank erosion. Therefore, for this report, it is assumed that Alternative Plan No. 1 will control 90 percent, or 42,300 cubic yards (.90 X 47,000 cubic yards), of the current sediment load.

The current contract price for dredging the Cuyahoga River navigation channel at Cleveland is $6.15 per cubic yard. This price includes dredging of the navigation channel, transporting the dredged material to the diked disposal site (Dike 14), and pumping the dredged material into the diked disposal site. It is assumed for this report that the cost for open-lake disposal would be the same since the time saved in not pumping the dredged material into the diked disposal site would be used in transporting the dredged material to the open-lake disposal site. Therefore, the average annual benefit that would be realized for reduced dredging requirements at Cleveland Harbor as a result of controlling annual streambank erosion under scenario 1 (open-lake disposal) for Alternative Plan No. 1 is $6.15 per cubic yard X 42,300 cubic yards controlled per year, or $260,100 per year.

Alternative Plan No. 2 was formulated to control the major areas of annual streambank erosion which produce about 85 percent of the total sediment load. Therefore, the average annual benefit for Alternative Plan No. 2 under scenario 1 is 85 percent of the average annual benefit for Alternative Plan No. 1, or $221,000 per year.

Scenario 2 assumes continue diked disposal of the sediment dredged from Cleveland Harbor for the entire 50-year economic life of the project. Therefore, the average annual benefit that would be realized by implementing either Alternative Plan No. 1 or No. 2 will be the difference in average annual costs of providing diked disposal sites under existing conditions versus improved conditions plus the average annual benefit for reduced dredging as estimated above.

The cost of constructing Dike 14 at Cleveland Harbor is currently estimated at $32,300,000 (including AE&D and S&A). When completed (Fall 1979), Dike 14 will have a capacity of approximately 6,100,000 cubic yards of sediment. Therefore, based on the current average volume of sediment annually dredged from Cleveland Harbor (860,000 cubic yards per year), Dike 14 has a capacity to store seven years of maintenance dredging. It is assumed for this report that a similar type diked disposal site, of approximately the same construction cost, will be required every seven years to contain future maintenance dredging. The average annual cost of providing these future diked disposal facilities is determined by calculating the present worth of the construction cost of these future diked disposal areas and converting this sum to an average annual charge based on a 50-year economic life and 7-1/8 percent interest rate. These calculations are shown in Table D2.1 and, as indicated, the average cost of providing these future diked disposal sites is $6,017,000 per year.

Alternative Plan No. 1 will control 42,300 cubic yards of sediment per year and will thus reduce the required maintenance dredging at Cleveland Harbor by 5 percent (42,300 divided by 860,000). Therefore, a seven-year diked disposal site under present conditions will store 7.35 years of maintenance dredging under improved conditions. The average annual cost of providing future diked disposal facilities under improved conditions is estimated in the same manner as under existing conditions and, as shown on Table D2.2, is $5,897,700 per year.

The difference in average annual charges for providing future diked disposal sites between existing conditions and improved conditions under Alternative Plan No. 1 is $119,300 per year ($6,017,000 per year - $5,897,700 per year). Therefore, the total average annual benefit under scenario 2 for Alternative Plan No. 1 is $260,100 for reduced dredging costs, plus $119,300 for reduced diked disposal costs, or $379,400 per year.

Alternative Plan No. 2 was formulated to control the major areas of annual streambank erosion which produce about 85 percent of the total sediment load. Therefore, the average annual benefit for Alternative Plan No. 2 under scenario 2 is 85 percent of Alternative Plan No. 1, or $322,500 per year.

Table D2.1 - Average Annual Cost of Providing Diked Disposal Sites to Contain Maintenance Dredging at Cleveland Harbor Assuming Current Conditions

Year of New Diked Disposal Site	Construction Cost of New Diked Disposal Site 1/ ($)	Present Worth Factor 2/	Present Worth of Future Construction Cost ($)
0	32,300,000	1.0	32,300,000
7	32,300,000	.6177	19,951,710
14	32,300,000	.3815	12,322,450
21	32,300,000	.2357	7,613,110
28	32,300,000	.1456	4,702,880
35	32,300,000	.0899	2,903,770
42	32,300,000	.0554	1,789,420
49	4,600,000 3/	.0343	157,780
Total			81,741,120 4/

1/ November 1979 price levels.

2/ 7-1/8 percent interest rate.

3/ Economic life of the project is assumed to be 50 years. Therefore, only one-seventh of the construction cost of the new diked disposal site constructed in year 49 is included in this analysis.

4/ Average annual charge (50-year economic life, 7-1/8 percent interest rate) = .07361 X $81,741,120 = $6,016,964 per year, say $6,017,000 per year.

Table D2.2 - Average Annual Cost of Providing Diked Disposal Sites to Contain Maintenance Dredging at Cleveland Harbor Assuming Alternative Plan No. 1 is Implemented

Year of New Diked Disposal Site	Construction Cost of New Diked Disposal Site 1/ ($)	Present Worth Factor 2/	Present Worth of Future Construction Cost ($)
0	32,300,000	1.0	32,300,000
7	32,300,000	.6177	19,951,710
14	32,300,000	.3815	12,322,450
22	32,300,000	.2200	7,106,000
29	32,300,000	.1359	4,389,570
36	32,300,000	.0839	2,709,970
44	27,700,000 3/	.0484	1,340,680
Total			80,120,380 4/

1/ November 1979 price levels.

2/ 7-1/8 percent interest rate.

3/ Economic life of the project is assumed to be 50 years. Therefore, only six-sevenths of the construction cost of the new diked disposal site constructed in year 44 is included in this analysis.

4/ Average annual charge (50-year economic life, 7-1/8 percent interest rate) = .07361 X $80,120,380 = $5,897,661 per year, say $5,897,700 per year.

(2) Reduced Dredging Requirements at Cleveland Harbor as a Result of Preventing the Formation of Potential Meander Changes - As previously discussed, the streambank erosion study indicated that there were seven locations on the Cuyahoga River where the existing high rate of annual streambank erosion was likely to produce a future change in the course of the river (potential meander change) (see Figures A2.4 to A2.7 in Appendix A). If these potential meander changes were to occur, they would introduce an additional 125,000 cubic yards of sediment into the river system which would require maintenance dredging at Cleveland Harbor (see Table A2.24 in Appendix A). Therefore, a benefit would be realized for preventing the formation of these seven potential meander changes. (Since both Alternative Plans No.1 and No. 2 will prevent the formation of all seven potential meander changes, the benefits realized for both alternatives will be the same).

Based on the current contract price for dredging the navigation channel of \$6.15 per cubic yard, the benefit realized for preventing the formation of the seven potential meander changes under scenario 1 (open-lake disposal) is 125,000 cubic yards X \$6.15 per cubic yard or \$768,750. This benefit would be realized, however, only once. In addition, since these potential meander changes will occur in the future, this benefit must be discounted to present conditions.

The average annual benefit realized by preventing the formation of the seven potential meander changes is estimated as follows: (1) assume all seven potential meander changes will occur 10 years in the future in order to maximize benefits for this Preliminary Feasibility Report; (2) calculate the present worth of \$768,750 expended ten years in the future based on an interest rate of 7-1/8 percent (\$768,750 X 0.50245 = \$386,258); and (3) convert the present worth of this future sum to an average annual charge based on a 50-year economic life and 7-1/8 percent interest rate (\$386,258 X 0.07361 = \$28,432, say \$28,400). The average annual benefit realized for preventing the formation of the seven potential meander changes for either Alternative Plan No. 1 or No. 2 under scenario 1 is, therefore, \$28,400 per year.

Scenario 2 assumes continued diked disposal of the sediment dredged from Cleveland Harbor. Therefore, in addition to the average annual benefit realized for reduced dredging at Cleveland Harbor, an additional benefit would be realized for reduced diked disposal capacity required.

As shown on Table D2.1, the average annual charge for providing diked disposal facilities under existing conditions is \$6,017,000 per year. Since 860,000 cubic yards of sediment are dredged annually, the short-term cost of providing diked disposal sites per cubic yard of sediment contained is approximately \$7.00 (\$6,017,000 ÷ 860,000). The benefit realized for reduced diked disposal capacity would, therefore, be 125,000 cubic yards X \$7.00 per cubic yard, or \$875,000. Converting this one time, future benefit to an average annual benefit, using the same method outlined above, yields an average annual benefit of \$32,400 (\$875,000 X 0.50245 X 0.07361 = \$32,362, say \$32,400). The total average annual benefit realized for preventing the formation of the seven potential meander changes for either Alternative Plan No. 1 or No. 2 under scenario 2 is, therefore, \$28,400 per year for reduced dredging, plus \$32,400 per year for reduced diked disposal capacity, or

$60,800 per year. (Note: A sensitivity analysis, changing the assumption that all potential meander changes occur 10 years in the future, to 20 years, 30 years, etc., was not conducted because no alternative was economically justified, as discussed later in this Appendix, and changing the 10 year occurrence assumption would reduce annual benefits.)

(3) Land Conservation - It is estimated that annual streambank erosion causes the loss of approximately 3.5 acres of productive land per year within the study area with an estimated value of $5,000 per acre. A benefit would, therefore, be realized for preventing the loss of this land. This benefit would be the same for both scenario 1 and scenario 2.

Alternative Plan No. 1 was formulated to control all existing annual streambank erosion. However, as previously discussed, it is assumed for this report that this alternative will only control 90 percent of the total. The average annual benefit realized would, therefore, be 3.5 acres saved per year X $5,000 per acre X 90 percent, or $15,750 per year (say $15,800 per year).

Alternative Plan No. 2 was formulated to control the major areas of annual streambank erosion which produce about 85 percent of the total sediment load. The average annual benefit for Alternative Plan No. 2 would, therefore, be 85 percent of the average annual benefit for Alternative Plan No. 1, or $13,400 per year.

(4) Flood Control - Flood control benefits would be realized by lowering the existing flood profile of the Cuyahoga River and its tributaries. However, since annual streambank erosion contributes a small percentage of the total sediment load carried by the river (the larger the sediment load carried by the river, the higher the flood profile is for any particular flow event), a reduction in sediment load through streambank erosion control plans would have no measurable effect in lowering the existing flood profile and no flood control benefit would be realized by implementing either Alternative Plan No. 1 or No. 2.

(5) Summary - Tables D2.3 and D2.4 present a summary of the average annual benefits that would be realized by implementing Alternative Plans No. 1 and No. 2, respectively. As indicated, the total average annual benefits for Alternative Plan No. 1 are $304,300 per year under scenario 1 (open-lake disposal) and $456,000 per year under scenario 2 (diked disposal). Total average annual benefits for Alternative Plan No. 2 are $262,900 per year under scenario 1 and $396,700 per year under scenario 2.

The benefit categories discussed above do not include the benefits that would be realized for preventing future damage to local roads and railroad facilities. These benefits would consist of costs avoided in repairing the damage and extra transportation costs avoided in rerouting traffic during repair of the damage. As discussed in Section C of the Main Report, one of the economic criteria under which plans of improvement were formulated for this report was that "Each separable unit of improvement or purpose should provide benefits at least equal to its cost unless justifiable on a noneconomic basis." Since benefits realized from preventing future damage to local roads

Table D2.3 - Summary of Average Annual Benefits for Alternative Plan No. 1 (Total Streambank Stabilization)

Benefit Category	Average Annual Benefits - Scenario 1 1/ ($ per year)	Average Annual Benefits - Scenario 2 2/ ($ per year)
1. Reduced Dredging Requirements at Cleveland Harbor as a Result of Controlling Annual Streambank Erosion	260,100	379,400
2. Reduced Dredging Requirements at Cleveland Harbor as a Result of Preventing the Formation of the Seven Potential Meander Changes	28,400	60,800
3. Land Conservation	15,800	15,800
4. Flood Control	0	0
Total	304,300	456,000

1/ Scenario 1 assumes open-lake disposal of dredged material at Cleveland Harbor.

2/ Scenario 2 assumes continued diked disposal of dredged material at Cleveland Harbor.

Table D2.4 - Summary of Average Annual Benefits for Alternative Plan No. 2 (Critical Area Streambank Stabilization)

Benefit Category	Average Annual Benefits - Scenario 1 1/ ($ per year)	Average Annual Benefits - Scenario 2 2/ ($ per year)
1. Reduced Dredging Requirements at Cleveland Harbor as a Result of Controlling Annual Streambank Erosion	221,100	322,500
2. Reduced Dredging Requirements at Cleveland Harbor as a Result of Preventing the Formation of the Seven Potential Meander Changes	28,400	60,800
3. Land Conservation	13,400	13,400
4. Flood Control	0	0
Total	262,900	396,700

1/ Scenario 1 assumes open-lake disposal of dredged material at Cleveland Harbor.

2/ Scenario 2 assumes continued diked disposal of dredged material at Cleveland Harbor.

and railroad facilities apply to specific sites, and not to the study area as a whole, they were not included in the determination of the economic efficiency of the plans of improvement formulated for this report which address the total study area. If the recommendation of this report is to continue into Stage 3 planning, these benefits will be estimated and included in the economic analysis of the recommended alternatives. However, if the recommendation of this report is to terminate the study for economic or other reasons, separate recommendations will be made for these specific sites.

c. ECONOMIC EVALUATION - Two measures of economic efficiency were developed for each of the alternative plans of improvement. They are: (1) Benefit-cost ratio; and (2) net average annual benefits. They are presented in Table D2.5 for scenario 1 and D2.6 for scenario 2. As indicated, no alternative plan of improvement has a benefit-cost ratio greater than 1.0 nor positive net average annual benefits. Thus, no alternative plan exhibits economic efficiency.

D3. UPLAND WATERSHED COMPONENT

a. GENERAL - The upland watershed component study area consists of the 303 square-mile drainage area of the Cuyahoga River between Independence (river mile 13.8) and Old Portage (river mile 40.25) (see Figure A1.1 in Appendix A). For the purpose of this report, sources of sediment from the upland area were divided into two source types: (1) diffuse nonpoint sources (sheet and rill erosion); and (2) identifiable nonpoint sources (gully erosion on disturbed areas). These two sources of erosion are discussed below.

The 303 square-mile drainage basin was divided into seven subwatersheds for the diffuse nonpoint source erosion study. These seven subwatersheds are Mud Brook, Brandywine Creek, Tinkers Creek, Chippewa Creek, Furnace Run, Yellow Creek, and the local drainage of the Cuyahoga River (see Plate A3-1 in Appendix I). As discussed in Appendix A, studies for five of the seven subwatersheds were completed for this report. Studies for the remaining two subwatersheds (Brandywine Creek and Yellow Creek) will be completed in the Fall of 1979, and the results will be reported in the Final Feasibility Report if the recommendation of this report is to continue into Stage 3 planning.

The results of the studies presented in Appendix A for the five completed subwatersheds indicated that critically eroding areas (areas with existing sheet and rill erosion above the tolerable soil loss value) produce about 590,000 cubic yards of sediment per year. Of this 590,000 cubic yards of sediment, it is estimated that approximately 350,000 cubic yards are transported by the Cuyahoga River to Cleveland Harbor and requires annual maintenance dredging. This volume of sediment represents about 41 percent of the total volume of maintenance dredging required at Cleveland Harbor.

As discussed in Appendix C, management programs were developed for each of the five subwatersheds to control the diffuse nonpoint sources of erosion. These management programs will be implemented (constructed) by individual landowners. It is assumed for this report that these management programs are self-liquidating. That is, individual landowners will realize benefits equal to or greater than the cost of implementing these management programs.

Table D2.5 - Economic Efficiency of the Proposed Plans of Improvement - Scenario 1 1/

	Average Annual Charges 2/ ($ per year)	Average Annual Benefits 3/ ($ per year)	Benefit-Cost Ratio 3/	Net Average Annual Benefits 3/ ($ per year)
Alternative Plan No. 1	821,600	304,300	0.37	-517,300
Alternative Plan No. 2	535,500	262,900	0.49	-272,600

1/ Scenario 1 assumes open-lake disposal of dredged material at Cleveland Harbor.

2/ From Tables C2.26 and C2.27 in Appendix C.

3/ Does not include the average annual benefits that would be realized from preventing damage to local roads and railroad facilities.

Table D2.6 - Economic Efficiency of the Proposed Plans of Improvement - Scenario 2 1/

	Average Annual Charges 2/ ($ per year)	Average Annual Benefits 3/ ($ per year)	Benefit-Cost Ratio 3/	Net Average Annual Benefits 3/ ($ per year)
Alternative Plan No. 1	821,600	456,000	0.56	-365,600
Alternative Plan No. 2	535,500	396,700	0.74	-138,800

1/ Scenario 2 assumes continued diked disposal of dredged material at Cleveland Harbor.

2/ From Tables C2.26 and C2.27 in Appendix C.

3/ Does not include the average annual benefits that would be realized from preventing damage to local roads and railroad facilities.

Benefits realized would include, but not be limited to, the following: (1) reduced maintenance cost and increased life of drainage systems which presently become clogged with sediment; (2) reduced property damage caused by land slips, sediment overflow, etc.; (3) increased utilization of recreation land which is currently subject to high erosion rates and which would be damaged if intensively used in its present condition; (4) stabilization of topsoil that would require replacement if lost, particularly in urban areas; and (5) reduced fertilizer costs to farmers who must replace nutrients lost when their fields are eroded.

Identifiable nonpoint sources of erosion refer to those areas where highly visible gully erosion is taking place. As discussed in Appendix A, identification of these source areas was confined to the Standard Project Flood area for the Cuyahoga River. The reason for this decision was that the sediment produced in these source areas, due to their proximity to the river channel, is generally delivered directly to the river and causes an immediate impact on the river system.

As discussed in Appendix A, 36 identifiable nonpoint sources of erosion were identified for this report. However, due to time constraints, the quantity of sediment produced from these source areas was not determined. In addition, management programs to control the gully erosion occurring in these source areas were also not developed. These items will be completed during Stage 3 planning. Therefore, the economic efficiency of these management programs will not be determined for this report, but will be completed during Stage 3 planning.

b. ESTIMATE OF AVERAGE ANNUAL BENEFITS - This section presents an estimate of the average annual benefit that would be realized from implementation of the management programs developed in Appendix C to control diffuse nonpoint sources of erosion. The only benefit category that will be investigated for this report is the average annual benefit that would be realized by the Federal Government as indicated by reduced dredging requirements at Cleveland Harbor. (As previously mentioned, it is assumed for this report that individual landowners will realize benefits equal to or greater than the cost of implementing management programs to control upland erosion.) This benefit will then be compared with the cost of continued Federal involvement in the upland area to determine if further Federal involvement in the upland area is warranted.

As previously discussed, sheet and rill erosion (diffuse nonpoint sources of erosion) on critically eroding areas in the five subwatersheds studied for this report produce about 350,000 cubic yards of sediment that requires annual maintenance dredging at Cleveland Harbor. If the management programs formulated for these eroding areas are implemented, it is estimated that 90 percent, or 315,000 cubic yards, of the existing volume of sediment produced from sheet and rill erosion will be controlled.

Based on the current contract price for dredging the Cuyahoga River navigation channel of $6.15 per cubic yard, the average annual benefit that would be realized by the Federal Government for reduced dredging requirements at Cleveland Harbor is $6.15 per cubic yard X 315,000 cubic yards controlled, or

$1,937,000 per year. Since average annual benefits of similar magnitude can be expected from implementation of management programs to control sheet and rill erosion in Brandywine Creek and Yellow Creek subwatersheds and gully erosion on identifiable nonpoint sources of erosion, and since the total cost of continued Federal involvement is only $55,000 (see Section F of the Main Report - "Study Management"), it is readily apparent that continued Federal involvement in the upland area is economically justified.

(Note: The above discussion does not consider the additional savings that would be realized by the Federal Government for reduced diked disposal capacity required to contain maintenance dredging at Cleveland Harbor. Since a significant benefit would be realized for reduced dredging costs alone, it was not necessary to estimate this additional benefit to economically justify continued Federal involvement in the upland area).

APPENDIX E

REPORTS OF OTHERS

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
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APPENDIX E
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EROSION AND SEDIMENTATION IN THE CUYAHOGA RIVER BASIN

by Robert P. Apmann*

INTRODUCTION

There are at least two reasons for studying the erosion and sedimentation problems of the Cuyahoga River Basin: (a) to define the magnitude and extent of these problems and (b) to predict the effect of remedying them. These objectives can perhaps be explained better in the form of questions.

Would a reduction in the sediment loads carried by the Cuyahoga River be beneficial? What would be the benefits to the plants and animals in the river, to municipal, commercial, and agricultural users of the river water, to navigation interests, to recreational users of the river, to property owners, to those who enjoy the beauty of the river, and to Lake Erie and its users? What methods of reducing the sediment loads will maximize benefits while minimizing deleterious effects? How should trends in population growth and land use be accounted for in trying to attain these benefits?

The process of answering these questions is very complex, since we are trying to analyze the complicated operation of a natural water system. To make a start we need to have basic information on the sources and production rates of sediments in the basin, the rates at which sediments

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EXHIBIT

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are transported, and the manner in which sediments are removed from the basin or deposited. We can approach the first objective through formulating an equation for the conservation of sediment mass in the watershed, in which that basic information on production, transportation, and deposition is used to trace the sediment motion. The second objective can be realized by modifying the original material balance equation to account for the effect of any planned protective works or projects on the erosion and sedimentation process. For example, if an armoring revetment is established on an eroding bank, an actual source of sediment might be lost. Since this process will modify the ability of a stream to erode material there will be a tendency for erosion and deposition to create a new pattern of channel configuration and to bring about different quantities of sediment production from the watershed. Subsequently, we would analyze the effects of the anticipated conditions on the river and protective works themselves, the biology of the river, and on the many users. These considerations might lead to modifications in the planned works so that the benefits would be increased while deleterious effects were eliminated. Ultimately, an optimum plan ought to be developed which would best attain the objectives of the entire project.

Unfortunately, the state of present knowledge regarding both sedimentation processes and their magnitude in the basin is inadequate to produce the desired results to a high degree of precision. Much of the sediment material balance relation will have to remain relatively imprecise or be expressed in qualitative terms. With this understanding, the

principles underlying the sediment processes in the Cuyahoga River watershed will be briefly described, present knowledge of amounts of sediment produced will be analyzed, and an overall plan for further studies will be outlined.

The Sediment Cycle

The sediment cycle is a never-ending series of processes which tend to remove particles from their places on the earth's surface and carry them down lower toward the sea. Temporarily the cycle may be interrupted or altered at one place or another as mountains are built or land is lifted up by other geologic actions; but during the typical human lifetime these latter, comparatively slow processes are seldom noticed, nor do they play such an important part in human activities as do erosive processes. Erosion too often becomes catastrophic. A large flood can cause the loss of hundreds or thousands of acres of farmland as a river cuts a new channel, creating severe hardship for many people. The hardship may be more direct. In 1964, an earth slide filled the reservoir of the Vaiont Dam in Italy, creating a flood wave which killed almost 2,000 persons.

The long-term results of erosion, though less spectacular, are nevertheless important. Before efforts were undertaken to control erosion on the Missouri River, that stream eroded an average of 9,100 acres a year, which was equivalent to destroying and rebuilding its entire meander belt every 70 years (1). Thus, were he able, a man could have seen during his lifetime the complete reworking of the Missouri River floodplain.

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(1) Task Committee on Preparation of Sedimentation Manual, "Sediment Control Methods: B. Stream Channels", J. Hyd. Div., ASCE, Vol. 98 (HY7): 1302, July 1972.

The basic stages in the sediment cycle are erosion, transportation, and deposition. Initially, the rock materials in a geographic unit are broken down by weathering into particles small enough to be moved, and these, together with existing sediments, are subjected to erosion. Mass movements of soil and rock, land erosion by rainfall and surface runoff, the solution of materials, erosion in channels and by flood flows, and scour by ice are the principal erosive processes in a watershed. In addition, cultural development -- the building of roads and buildings and the discharge of waste products by man -- are important sources of sediments.

Following their erosion the sediments are transported, or carried away. This might be through sliding, creeping, or falling, or by the action of air, as in a windstorm, or by water or by ice. The water flows may be through the ground, in which only the finest particles will be carried and then only at very slow rates, or over the ground by surface runoff. Surface runoff, which is produced by rainstorms or snowmelt, is capable of carrying the smaller-sized particles, and when these reach a stream channel they are usually sufficiently fine so that the flow in the stream carries them downstream without their being deposited in the channel. This portion of the sediment load carried by a stream and which has been eroded from the watershed surface, rather than from the channel itself, is called the "wash load", probably because it tends to wash through a reach and not be deposited. What is termed the "bed load" and the "suspended load" of a stream consist only of material which has been eroded from the channel itself, although the wash load too moves in

suspension. Bed load moves primarily in contact with the stream bed, by rolling, jumping, or sliding, while the suspended load is carried throughout the flow depth by the action of fluid turbulence.

It is debatable whether there is a clear distinction between bed load and suspended load, and as the stream depth and velocity increase, some of the particles which were previously moving in contact with the bed become part of the suspended load. Both bed load and suspended load movement are governed by the same fluid forces. Probably a more significant distinction should be made, and that is the difference between measured suspended load and unmeasured load. The sampling devices used to measure sediment load on the Cuyahoga River are not capable, because of their construction, of sampling the sediment which is being transported within $3\frac{1}{2}$" of the river bottom. This may be a substantial fraction of the total sediment load. Only the suspended load portion is reported as data and no effort is made to estimate or determine the unmeasured load. That fraction remains largely unknown and its magnitude has to be determined indirectly or estimated by mathematical analysis.

<u>Sediment Material Balance</u>

At the upstream end of any reach of the river, a certain quantity of sediment is carried into the reach by the flowing water. Wind may carry over and deposit onto the watershed surface some amounts of solid material, and construction and refuse collection activities may add material to the portion of the watershed draining into the reach. At the downstream end of this reach the river will carry out sediments, and wind, construction, and other activities may also result in the removal of material from either the river or the watershed surface.

Within the reach some deposition by water may occur.

In the framework of the Restoration Project, the major concern is for the sediments derived from and carried through the action of water. Since construction work may alter the erodibility of the soil, its impact on that process must also be considered.

The difference between the quantities of sediments carried into a reach by water and carried out from the same reach, neglecting other means of transport, represents the net production of sediment in the reach and its watershed. The processes of erosion and deposition are usually occurring in a watershed simultaneously at different places, so that the net production refers to the amount of sediment which has been eroded and not deposited in the time interval being studied.

For instance, a short rainstorm might erode a large number of fine particles over the whole land surface, but because of the short length of time involved, there would be insufficient time for those particles to be moved a great distance, and most of them would be redeposited quickly. Only the particles near a tributary would actually be able to enter a flowing stream and be carried rather swiftly away. Simultaneously, those particles would be replaced by others which were originally farther upslope, and so on, until the particle eroded highest up in the watershed moved down a bit to replace another.

In a similar way much of the material eroded in river channels moves in steps. That material removed from the outside of a river bend is deposited downstream, usually on the inside of the second bend away, to form a point bar while material from that bend is moving down toward

another bar. The portion of the channel sediment which is leaving a reach has probably been eroded from very close by, and the material entering the reach at the upstream end has similarly been derived from just a short distance away.

The sediment material balance equation for a reach can be expressed as:

$$\Delta G_s = G_{s_2} - G_{s_1} \quad \ldots\ldots\ldots \quad (1)$$

in which ΔG_s = net production of sediment in a reach of stream due to the processes of sediment erosion and deposition which act in the reach and its watershed, G_{s_1} = rate at which sediment is transported into the reach of stream, and G_{s_2} = rate at which sediment is transported out of the reach of stream. In turn,

$$\Delta G_s = \sum_{j=1}^{n} (E_j - D_j) \quad \ldots\ldots\ldots \quad (2)$$

in which the net production of sediment is expressed as the sum of all the rates of production, E_j, less the deposition rates, D_j, due to the sources of sediment. Each source, such as land erosion, is symbolized by a separate subscript j, with j having values from 1 to n. Depending on the approach, there will be about 7 distinct sources of erosion, so that n will be about 7.

The problem now is to separate the sources of sediment and evaluate the rates of erosion and deposition. This has been done in a preliminary manner, and the results of those estimates will be analyzed.

SEDIMENT PRODUCTION IN THE CUYAHOGA RIVER BASIN

Two recent estimates of sediment production in the Cuyahoga River Basin have been made. Sveum used data on quantities of materials dredged from the Cleveland Harbor (2). The Northeast Ohio Water Development Plan (NEOWDP) restudied earlier work by the Soil Conservation Service (SCS) (3).

In the first study it was determined through assembled records of dredging by the U.S. Army Corps of Engineers in the Cleveland Harbor that in the ten-year period from 1959 to 1968 an average of 1,242,000 cubic yards (cu. yds.) of sediment was deposited each year in that basin. From analyses of samples of the dredged material it was determined that 48% of this, or 597,000 cu. yds., was flue dust or other waste products. Thus, 645,000 cu. yds. would have been derived from erosion and sedimentation in the Cuyahoga River watershed. Sveum implied that the Harbor trapped all the sediments which were delivered to it by the river.

This yardage can be converted to weight. Sveum assumed a bulking factor of 15% from inplace to scow measure and a dry-weight density of 50 pounds per cubic feet. Working backward then, the entire watershed would produce 379,000 tons of sediment each year. This analysis does neglect the load carried through the Harbor to the Lake. In order to adequately analyze the sediment mass balance in the watershed, the amount of these fine sediment which pass through the Harbor must be estimated.

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(2) David L. Sveum, "The Quantity and Quality of Sediments Deposited in Cleveland Harbor, Cleveland, Ohio", Proceedings, Seminar on Sediment Transport in Rivers and Reservoirs, Hydrologic Engineer Center, Corps of Engineers, April 1970, Paper No. 8.

(3) U.S. Dept. of Agric., SCS, "Survey Report, Cuyahoga River Watershed, Ohio", 1952.

This can be done by calculating the proportion of various grain sizes deposited in the Harbor. Mechanical analyses of the suspended sediment particle size distribution have been performed by the U.S. Geological Survey (USGS). Two of these analyses are plotted in Figure 1 on a log probability plot of grain size in millimeters against the percent of sample finer than that size. The two analyses represent limits; both the finest and coarsest samples taken out of 20 in past years. The line marked "mean" is the average of the 20.

Assume that deposition of the suspended load begins roughly at Denison Avenue and that the particles settle through completely quiet fluid over a longitudinal distance of 40,000 feet, this being roughly the harbor length. The depth of the harbor is taken as 25 feet, the mean discharge as 800 cfs and the cross-sectional area as 10,000 sft. The mean forward flow velocity will be 0.08 ft/sec. for those assumed conditions. The smallest particle which will completely settle out is one which, being initially located at the surface, will fall 25 feet over the 40,000 foot distance. To traverse the 40,000 feet at 0.08 feet per second will require 500,000 secs. The fall velocity which will just allow a particle to drop 25 feet in that time is W = 0.0015 cm/sec. According to Krumbein and Pettijohn (4), this is equivalent to a particle diameter of 0.004 mm. In other words, all particles larger than 0.004 mm will settle out in the harbor. Varying proportions of finer particles will be carried into the lake. This will depend on their fall velocities and how far they can drop over the harbor length.

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(4) W. C. Krumbein and F. J. Pettijohn, Manual of Sedimentary Petrography, Appleton-Century-Crofts, Inc., New York, 1938, p. 166.

This percentage of other sizes can be calculated by assuming they are initially uniformly distributed with depth and then calculating how far they fall in 500,000 secs. That distance divided by 25 feet will be the fraction retained in the harbor. The results are displayed in Table I, and indicate that based on the annual mean discharge and suspended load grain size characteristics about 28% of the suspended load finds its way to Lake Erie without being deposited in the harbor. The long-term average suspended sediment load passing the Independence gage is 211,000 tons and thus about 59,000 tons/year goes directly to Lake Erie.

This percentage, while appearing high, may be too low. During peak flows, when most of the sediment is carried down the river, even much larger particles and higher proportions will be carried into the lake. A more accurate means of calculating the amount would be to consider the delivery of particles to the lake for higher flows and route the hydrographs which have been measured in the past.

In order to estimate the sediment production by the entire watershed, we return to Sveum's figure of 379,000 tons/year and add the estimate of 59,000 tons/year for the amount of suspended material carried out to the lake. The total is about 440,000 tons/year.

On the other hand, the suspended sediment records taken by the USGS at Independence indicate a much smaller amount. To compare the two figures, it is necessary to proportion the yields by the drainage area, taking into account at the same time that Lake Rockwell traps about 90.5% of the sediments produced in the upper 204 sq. mi. of the watershed.

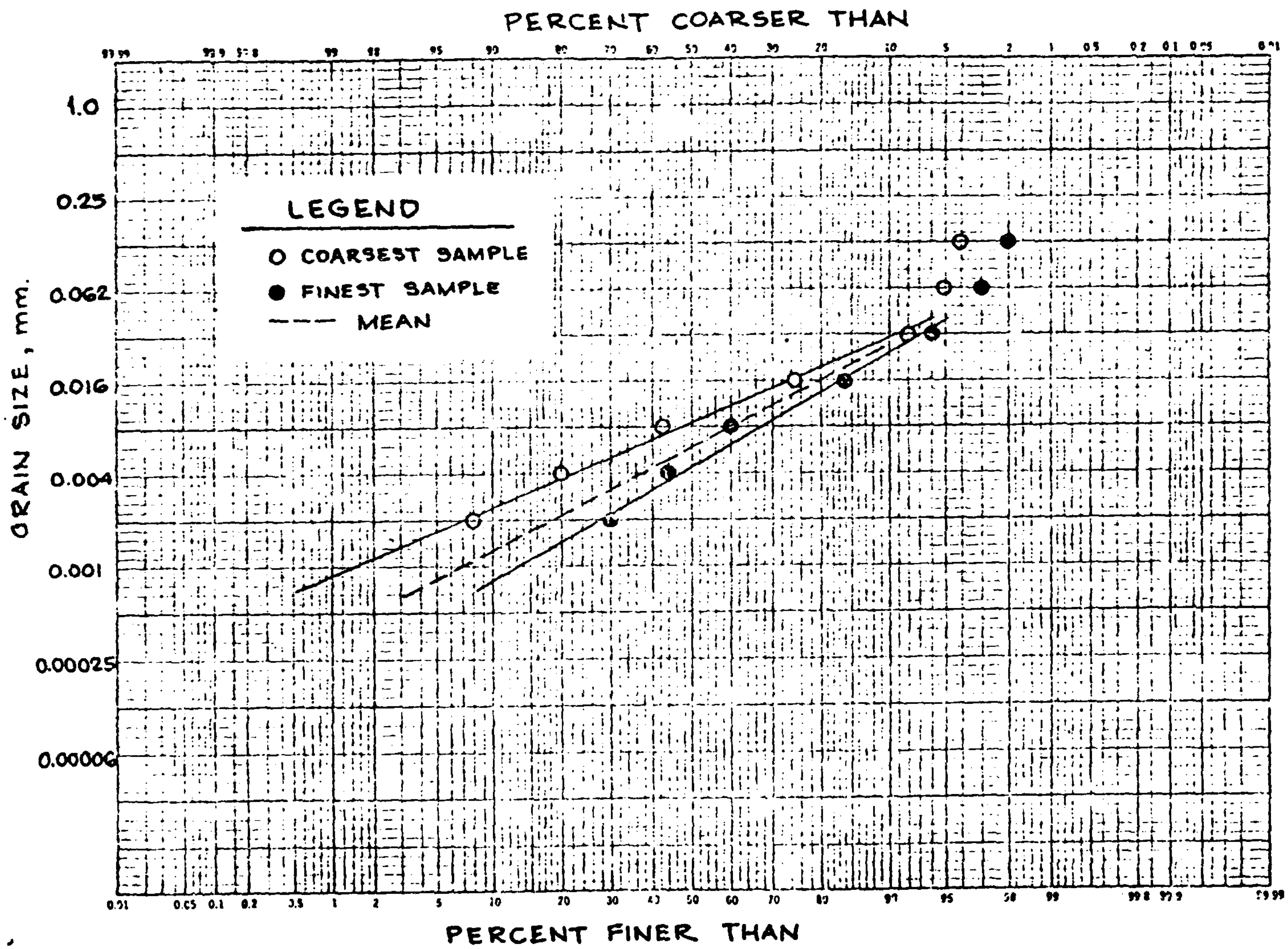

Figure 1. Size Analysis of Suspended Sediment Samples

Table I

Fraction of Suspended Load Carried Through Cleveland Harbor

(1) Grain Size d_s	(2) Fall Velocity	(3) Depth of Fall		(4) Fraction Passed	(5) Weight Fraction of Load	(6) Weight Fraction to Lake Erie
(mm)	(cm/sec)	(cm)	(ft)			
.00276	.00068	340	11.	0.56	0.14	0.078
.00195	.00034	170	5.6	0.77	0.08	0.062
.00138	.000168	84	2.8	0.89	0.06	0.053
.00098	.000085	42	1.4	0.93	0.04	0.037
.00069	.000043	21	0.70	0.97	0.02	0.019
.00049	.000021	10	0.35	0.99	0.016	0.016
.00034	.000010	5	0.17	1.00	0.010	0.010
					Total	0.275

(4) Fraction passed - fraction of grains of diameter, d_s, which are not retained in the Harbor.

(5) Weight fraction of load represents the proportion of the suspended sediment load made up by the grains in the interval whose median size is d_s.

(6) Weight fraction to Lake Erie is the product of columns (5) and (6).

The watershed area above the Independence gage is 707 sq. mi., and above the Harbor is 810 sq. mi. To estimate the yields from these areas, we subtract the inflow to those areas from Lake Rockwell, which is about 4,000 tons/year.

The subscript 1 refers to the outlet from Lake Rockwell, 2 to the Independence gage, and 3 to the mouth of the river. Then:

$$G_{s_{1\to3}} = G_{s_3} - G_{s_1} \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$= 440{,}000 - 4{,}000 = 436{,}000 \text{ tons/yr.}$$

Also,

$$\frac{G_{s_{1\to2}}}{G_{s_{1\to3}}} = \frac{A_{1\to2}}{A_{1\to3}} = \frac{707-204}{810-204} = 0.830 \quad \ldots\ldots \quad (4)$$

in which A = watershed area in sq. mi. Then, the total sediment yield at Independence ought to be

$$G_{s_2} = G_{s_{1\to2}} + G_{s_1} = 362{,}000 + 4{,}000$$

$$= 366{,}000 \text{ tons/yr.}$$

This figure can be compared to the suspended sediment yields at Independence measured by the USGS since 1951. These have averaged 211,000 tons/year. The difference of 155,000 tons/year represents the unmeasured load which passes near the stream bottom below the sediment sampler. This unmeasured load generally consists of the coarser-size particles derived from channel erosion, gully formation, and flood plain scour.

The Soil Conservation Service analysis indicated that 54% of the

sediment derived from the watershed was from stream channel erosion. Since the sediment flowing out of Lake Rockwell is all fine material, the amount of sediment from channel erosion between there and Independence would be 198,000 tons/year (0.54 x 366,000). It is further assumed that all of the 155,000 tons/year unmeasured load is due to channel erosion. Thus, 43,000 tons/year of the measured suspended load is also due to channel erosion. We recall that 4,000 tons/year of suspended load came from Lake Rockwell, so that sheet erosion and miscellaneous sources supply 164,000 tons/year of suspended sediment. Dividing by the 503 sq. mi. watershed area gives a yield of 326 tons/year/sq. mi.

This latter figure can be compared to the yield of the watershed above Lake Rockwell. According to the 1950 SCS reservoir surveys the average annual yield of the upper watershed was 41,800 tons/year, which translates to 204 tons/year/sq. mi. Channel erosion appears to be of minor importance, so that most of the yield is derived from sheet erosion. This upper watershed has denser plant cover which could create lower yields. As stated earlier, 90.5% of this sediment is trapped by Lake Rockwell, allowing an average of 4,000 tons/year to pass into the lower reaches of the river.

The Northeast Ohio Water Development Plan, in the section "Agricultural Aspects", approached the analysis in a different way. They estimated gross erosion and applied a delivery ratio, which is an empirically determined factor. Thus, the gross soil erosion in the Cuyahoga Basin was estimated at 272,000 tons/year, main stem streambank erosion at 426,000 tons/year, and it was estimated that city and industry contribute 100,000 tons/year. Since not all of this eroded material reaches a

stream because of deposition, a delivery ratio was applied to calculate the amount becoming suspended load. 30% of the streambank material appeared to be clay, inferring a ratio of 0.30 for that source. A ratio of 0.20 was applied to the soil erosion and 0.50 for industrial. The results of this analysis appear in Table II and can be seen to agree closely with the suspended sediment measurements of the USGS.

This estimate, however, neglects entirely the unmeasured load, and it is suspected that the delivery ratios and loads have been adjusted to make the load estimate equal the suspended load measurements. In addition, the effect of Lake Rockwell, which could have been easily included through applying equation (1), has been calculated through using a gross delivery ratio.

The estimate derived from the Northeast Ohio Water Development Plan could be considered unreliable. However, serious questions can also be raised about the analysis which has been outlined here, based on dredging records and the Soil Conservation Service analysis. For instance, how can we be sure that 48% of the sediment material is flue dust? Is 54% of the sediment yield due to channel erosion? Exactly how much of the total load passing the Independence gage is not being measured?

If we had more information on the river and its behavior, we could apply other analyses to the flow in order to estimate unmeasured load. This would add a measure of confidence to the analysis of sediment production from the Cuyahoga River Basin.

Estimated Total Load

The total load which the river ought to carry has been roughly calculated based on the channel and flow characteristics at Independence

for a discharge equal to the average annual discharge.

The unmeasured suspended load was estimated as 19,000 tons/year, using a technique described by Brooks (5). The data used for these calculations included the published grain size curves of the USGS in order to obtain the amount of sediment of each size fraction in suspension. For a discharge of 800 cfs, the average annual, published data gave the average velocity as 2.30 feet per second, cross-sectional area as 360 square feet, and the width as 77 feet. The additional calculated unmeasured load does not pass through to the lake, since only particles larger than 0.04 mm. diameter are significant in forming the unmeasured load.

The bed load estimate was made quickly from a chart prepared by Shulits and Hill (6) giving the load rate per foot width of channel for given sediment grain diameters and tractive forces. This chart was developed from the Meyer-Peter and Muller formula, reputedly one of the more accurate. The calculated bed load was 150,000 tons/year.

The estimated total load is the sum of the measured suspended load, the calculated unmeasured suspended load, and the bed load. This sum is 380,000 tons/year, which agrees closely with the estimate of 366,000 tons/year made by analyzing dredging records.

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(5) Norman H. Brooks, "Calculation of Suspended Load Discharge from Velocity and Concentration Parameters", Paper No. 29, Proceedings, Federal Inter-Agency Sedimentation Conference, 1963, USDA Misc. Publ. 970, U.S. Gov't. Printing Office, Washington, D.C. 20402.

(6) Sam Shulits and Ralph D. Hill, Jr., "Bedload Formulas", Hydr. Lab. Bulletin, Pennsylvania State University, University Park, Penna., Dec. 1968, p. 128.

The estimates are somewhat crude and a more complete analysis ought to be made by applying the calculation methods to the past history of flows.

From all these estimates of sediment production and the different measurements, it appears that considerable refinement is needed in the investigations in order to obtain more precise figures on net sediment production, to delineate production by source, and to more precisely estimate the locations of sediment production. In summary, the production of sediment in the Cuyahoga River Basin is believed at present to be given by the figures in Table III. These have been rounded off to two significant figures. Their accuracy is unknown.

Streambank erosion is estimated to be the major single source of sediment in the Lake Rockwell-Independence reach.

Table II

Sediment Yield from Cuyahoga River Watershed as Calculated in NEOWDP

(1) Source	(2) Gross Erosion Amount and Delivery Ratio		(3) Delivery
			Tons/year
Land Erosion	272,000 x 0.20	=	54,400
Streambank Erosion	426,000 x 0.30	=	127,800
City and Industry	100,000 x 0.50	=	50,000
	Total	=	232,200
	USGS, 20-yr. avg.	=	211,000

Table III

Sediment Production in the Cuyahoga River Watershed

(1) Source	(2) Sediment Production
	Tons/year
1. Total to Harbor from upland sources, 810 sq. mi.	440,000
2. Yield to Lake Rockwell, 204 sq. mi.	42,000
3. From Lake Rockwell	4,000
4. Yield, Lake Rockwell to Independence gage, 503 sq. mi.	360,000
a. Channel Erosion	200,000
b. Other Sources	160,000

SEDIMENT PRODUCTION WITHIN THE WATERSHED

In March 1972, suspended sediment sampling was begun at Tinker's Creek at Bedford, Ohio, and on the Cuyahoga at Old Portage, Ohio. Between March 13, 1972 and June 30, 1972, 169,125 tons passed by the Independence gage, 12,545 at Old Portage, and 19,727 past Bedford on Tinker's Creek.

Let those figures be proportioned upward by the factor 211,000/169,125 in order that the load for the Independence gage equal the average annual load. Then at Old Portage the load would be 15,656 tons/year, and at Bedford 24,670 tons/year. The yields from each sub-part of the Basin are listed in Table IV.

It appears that the portion of the Basin between Independence and Old Portage is by far the most prolific source of suspended sediment. These estimates are to be considered as preliminary, since the sampling took place over only part of a year.

Channel Erosion and Deposition

According to the preliminary estimates of sediment production made earlier, channel erosion is the principal sediment source in the Cuyahoga River Basin. The net production due to this source is estimated at about 200,000 tons/year in the watershed between Independence and Old Portage. This represents the difference between total channel erosion and channel deposition. It is important to analyze the physical aspects of the channel sedimentation process and how this relates to the behavior of the channel. We would like to find out why channel erosion is significant and also whether the estimate seems realistic.

Table IV

Suspended Sediment Yields Within
the Cuyahoga River Basin

(1) Location	(2) Area	(3) Yield
	Sq.Mi.	Tons/sq. mi.
Cuyahoga River, Old Portage to Lake Rockwell	200	38
Cuyahoga River, Independence to Old Portage (excluding Tinker's Creek)	219	798
Tinker's Creek at Bedford	83.9	293

A meandering stream moves back and forth across its floodplain in the course of time, eroding sediment from the outsides of stream bends and depositing it on the insides. When the flow of the river rises out of its banks to flood neighboring areas, some sediment is scoured from the floodplain and other material deposited in abandoned channels or depressions in the surface.

Movement of the fine material which has been derived from sheet erosion is relatively continuous, since it is easily carried by water. The coarsest material is moved discontinuously, being eroded from part of the channel and deposited a comparatively short distance downstream. If a topographic survey, including measurements of cross-sections, is made, it will appear over a long time period that erosion is taking place on one side of a channel and deposition on the other.

All along the stream channel the net movement would usually be in the downstream direction and toward one valley wall or another. In this way, a stream tends to move from side to side, reworking its deposits while the meandering bend pattern tends to move downstream. A soil particle which is once deposited in a bar may not be eroded again for from 100 to 1,000 years, in accordance with the rate of lateral migration of the particular stream. The floodplain therefore acts as a storehouse for sediment (7).

If, over a long time period, the stream neither aggrades nor degrades, the channel maintains a reasonably constant volume, although the process of meandering constantly changes the channel topography. Thus, the flood

(7) Luna B. Leopold, M. Gordon Wolman, John P. Miller, "Fluvial Processes in Geomorphology", W.H. Freeman and Co., San Francisco, 1964, p. 327.

plain represents only storage for sediment and not a net source for sediment. Inflow to the floodplain will equal outflow from it. Of course, the sediment flowing into a reach will not be the same sediment that is flowing out. Furthermore, the stream will assume a shape and slope that is just capable of transporting all the sediment that is fed to it from the watershed.

Under these circumstances, there will be no net deposition or erosion along the channel. The amount transported will be equivalent to the capacity of the stream for transportation, given unlimited availability of sediment to the water.

In an aggrading stream the bed is being generally raised by deposition and the floodplain volume increased. The sediment which is being contributed from upstream and tributary inflows is being partly stored in the floodplain. The result is that sediment yields from such a river are somewhat smaller downstream than for a similar watershed which would be in equilibrium.

Finally, suppose the floodplain is degrading. Then the stream will be cutting down through its floodplain while it meanders. The flood plain, and therefore bank erosion, is a real source of sediment. This process can continue for a long time if a downstream control is being eroded in the stream bed, allowing its elevation to fall.

Rate of Sediment Production by Channel Processes

The rate at which sediment is being produced by channel processes in the Cuyahoga is a critical question. The Soil Conservation Service indicated that 3,466 tons/mile/year were produced by the main stem. This

amounted to 54% of the total production estimate which they made. In a previous section this factor of 0.54 was used to obtain an estimate of 200,000 tons/year for channel erosion throughout the watershed. The 100,000 tons/year yield for the Independence to Old Portage Reach is based on the net erosion rate of 3,466 tons/mile, and does not consider subsequent deposition. The 200,000 tons/year figure therefore has been erroneously derived, since channel erosion may be some different percentage of total erosion than estimated in that study. Thus, both of these numbers represent guesses and orders of magnitude. In fact, although the bulk of informed opinion has concluded that the Cuyahoga is, in effect, removing sediment from its floodplain, there has been no real proof of this presented.

The hypothesis that net channel erosion is substantial in that reach can be proven or disproven by analyzing old survey records and maps and comparing them with more modern ones. Production rates can be estimated in this way, also. A substantial amount of effort is required, but a wide variety of information must be collected and analyzed in order to obtain a reasonably accurate answer to the question of production rate.

Some type of hypothesis must also be developed in order to explain why the Cuyahoga River is producing sediment from its floodplain. If we know what the cause of its behavior is we can seek to correct that cause and to predict the magnitude of its action in the future. We now know that the floodplain will produce sediment if the river channel behavior is not in equilibrium with the water discharge. Sediment production will continue to occur if equilibrium is not attained. For production to have continued over a long time period also implies a constantly grow-

ing disturbance in the watershed. It is tempting to suggest that the urbanization of the watershed, which has been taking place with ever-increasing activity in past years, has actually changed the river regime and is therefore the cause of the alteration of the sediment production.

It is worthwhile to investigate this possibility, since an analysis of the possible effects of urbanization on sediment yields, although crude, is another tool through which the behavior of the river can be studied.

Urbanization and Sediment Yield

The urbanization of a watershed generally causes the reduction of infiltration capacity by paving and the increasing concentration of runoff waters into storm sewers and constructed drainage channels. Both of these changes produce increases in water yield and peak discharge. At the same time, the sediment yield from the watershed may be reduced, although during and shortly after construction yields may rise substantially. Since construction in the Cuyahoga River watershed is a relatively constant process, sediment yields from that source are probably growing commensurately and steadily.

Given an increase in both peak discharge and average annual discharge, what ought to be the reaction of the stream channel?

Relationships have been empirically developed to relate width, depth, and flow velocity to mean annual discharge (8). Thus, for 128 gaging stations in the United States:

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(8) Luna B. Leopold and Thomas Maddock, Jr., "The Hydraulic Geometry of Stream Channels and Some Physiographic Implications", U.S. Geol. Survey, Prof. Paper 252, U.S. Gov't. Printing Office, Washington, D.C..

$$B = C_B Q^{0.12}$$

$$D = C_D Q^{0.45}$$

$$U = C_U Q^{0.43} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (5)$$

in which B = stream width, D = mean depth of flow, U = mean water velocity, and Q = mean annual discharge. C_B, C_D, and C_U are coefficients. Let it be assumed that the proportionality factors remain constant with a small change in Q. The area, A, of the cross-section will be equal to the product of B and D, or

$$A = C_B C_D Q^{0.12} Q^{0.45} = C_A Q^{0.57} \qquad \ldots\ldots\ldots \qquad (6)$$

Thus, as discharge Q, increases, the cross-sectional area will increase by the 0.57 power. A 10% increase in Q will create a 5.6% increase in cross-sectional area.

Also, let it be assumed that the Manning formula adequately represents the resistance relationships of the channel:

$$Q = \frac{1.5}{n} AR^{2/3} S^{1/2} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (7)$$

in which R = hydraulic radius, n = Manning retardance coefficient, and S = slope. Most natural channels are very wide and the mean depth, D, is virtually equal to the hydraulic radius. Substitution of the relations for area and depth yields

$$\frac{S}{n^2} = C_M Q^{-.48} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (8)$$

This relationship infers that increasing discharges will decrease the

slope while increasing the retardance coefficient. The latter factor will increase if the bed material size increases, which could occur if higher velocities were present to remove finer material present in the bed. The original relations do indicate slightly higher velocities. Another way in which channel resistance changes is through the formation of sand waves as the bottom, although this process is more characteristic of rivers having fine sand beds. Slopes could decrease either by degradation or channel lengthening, or a combination of both.

In order to predict volume changes that occur in response to discharge changes, we calculate volume as the product of width, length, and depth. Since slope represents elevation difference, ΔE, divided by stream length,

$$L = \frac{\Delta E}{n^2 C_M} Q^{.48} \qquad \text{. . . . .} \qquad (9)$$

If it is assumed that no degradation occurs and that resistance characteristics do not vary significantly with Q, then $L \propto Q^{.48}$. The stream channel volume, V, would then be related to discharge as

$$V = C_V Q^{.48} Q^{.57} = C_V Q^{1.05} \qquad \text{. . . . .} \qquad (10)$$

A change in discharge should then trigger a nearly proportional change in volume. Increasing the discharge will increase the stream channel volume. The material which is removed will be the sediment produced from the floodplain. This can be expressed as weight production per unit of time, t:

$$P(\text{tons/yr.}) = \frac{80}{2000} \cdot \frac{V_2 - V_1}{t} = \frac{V_1}{25t}\left(\frac{V_2}{V_1} - 1\right)$$

$$= \frac{V_1}{25t}\left[\left(\frac{Q_2}{Q_1}\right)^{1.05} - 1\right] \quad \ldots\ldots\ldots \quad (11)$$

in which V_2 and V_1 = the final and original channel volumes over a period of t years. The factor 25 converts cubic feet to tons.

The alternative method of creating sediment production from the floodplain is through degradation of the surface of the floodplain. The volume removed in a length of time t will be equal to the average drop in floodplain elevation, multiplied by the total stream length and the rate of bank cutting, C. The maximum drop in floodplain elevation would occur at the upstream end of a reach while there would be no relative degradation at the lower end. The average rate is then assumed to be half the maximum. From the slope-discharge relation, the elevation difference between the lower and upper ends of a reach is related to discharge as $Q^{-.48}$. At the same time, the cross-sectional area will have changed, producing some sediment from volume increase. Then

$$P(\text{tons/yr.}) = \frac{80}{2000}\,\frac{(\Delta E_1 - \Delta E_2)\cdot L\cdot C}{2t} + \frac{80}{2000}\,\frac{(A_2 - A_1)\cdot L}{t}$$

$$= \frac{\Delta E_1 LC}{50t}\left[1 - \left(\frac{Q_2}{Q_1}\right)^{-.48}\right] + \frac{V_1}{25t}\left[\left(\frac{Q_2}{Q_1}\right)^{.57} - 1\right] \quad \ldots \quad (12)$$

in which ΔE_2 = elevation difference after t years over length L, and ΔE_1 = elevation difference at beginning of period. C = rate of bank cutting in feet/year, and Q_2 and Q_1 = mean annual discharges at end and beginning of time period.

There have not been continuous records made of discharge over a long time period at Independence, but there was some discharge measuring done between 1903 and 1905. From those records, it can be inferred, although it is not certain, that for a given annual precipitation on the watershed the annual water yield at Independence has increased from 36% in 1904 to 55% in 1970, a period of 66 years. Assuming that this is true, the figures represent an average annual increase of about 0.68%, or a rate of 0.0068. Over the period of one year, the ratio $(Q_2/Q_1)^{1.05}$ = 1.007, $(Q_2/Q_1)^{.57}$ = 1.0039, and $(Q_2/Q_1)^{-.48}$ = .9966. Other important values are listed in Table V.

The bank cutting rate, C, can be calculated from items 4. and 5. in Table V, using the assumed unit weight of soil as 80 lbs/cubic ft:

$$C = \frac{(3,466)}{(5,280)} \frac{(2,000)}{(80)(15)} = 1.1 \text{ ft./yr.} \qquad \ldots\ldots\ldots \qquad (13)$$

Since the average width of the floodplain is about 1,500 ft., at that rate it would take the Cuyahoga 1,300 years to meander across its flood plain once. In some portions of the floodplain the bank cutting rate has most certainly exceeded 1.1 feet/yr. as evidenced by the channel changes documented in plates C-1 and C-2 of Appendix C, First Interim Report, Cuyahoga River Restoration Project.

Table V

Channel Characteristics, Cuyahoga River, Independence to Old Portage

Characteristic	Value
1. Length	30.6 miles = 162,000 feet
2. Floodplain Area	237,000,000 square feet
3. Channel Volume	130,000,000 cubic feet
4. Ave. Bank Height	15 feet
5. Bank Erosion	3,466 tons/mile
6. Elevation Difference	200 feet

Having these estimates of channel characteristics we can now use equations (11) and (12) to estimate production rates. Thus, assuming sediment to be produced only from changes in volume, we apply equation (11), and assuming production only through degradation, we apply equation (12).

From volume increase:

$$P(\text{tons/yr.}) = \frac{130,000,000}{25(1)}\left[1.007 - 1\right]$$

$$= 36,400.$$

This ought to be rounded off to only one significant figure, making the rate P = 40,000 tons/yr.

From degradation:

$$P(\text{tons/yr.}) = \frac{(200)(162,000)(1.1)}{(50)(1)}\left[.0034\right] + \frac{130,000,000}{(25)(1)}\left[.0039\right]$$

$$= 2,400 + 20,300 = 22,700, \text{ say } 23,000.$$

These estimates indicate that volume changes probably create more substantial sediment production than does degradation. They also indicate that the SCS estimate of 100,000 tons/yr. may be somewhat high, although the figures are about the same order of magnitude.

Thus, there is a need for additional quantitative information and for a more sophisticated analysis of the regime characteristics of the Cuyahoga River. The production of sediment should be analyzed in sufficient detail to permit the effect of corrective works to be predicted.

BANK STABILIZATION

Between Independence and Akron there are several reaches of the river which are essentially unstable. A comparison of the channel alignment in 1903 with that in 1967 shows that there are a number of places where the stream channel has meandered extensively. These locations are shown in plates C-1 and C-2, Appendix C, First Interim Report.

The meandering reaches are essentially those between the North Portage Path and Peninsula, Boston to the Brecksville Dam, and from the Brecksville Sewage Treatment Plant to Independence. If bank stabilization measures were applied to the unstable banks in these reaches, channel erosion would be essentially eliminated in the river between Independence and Akron and the channel alignment would be stabilized. There could be important benefits. Among those are a reduction in sediment carried to the harbor, elimination of land erosion through stream meandering, and improvement of the recreation potential of the river. Spawning conditions for game fish could be improved due to a reduction of fine particles in the stream bottom and increase of water depths in pools. A reduction in high water levels could be achieved, yielding some flood control benefits. The appearance of the river might be enhanced if colloidal particles in the bank were stabilized.

For the purpose of studying the feasibility of bank stabilization, it is assumed that the stabilization would essentially consist of treating eroding banks with crushed stone riprap on the lower slope, and planting the upper slope with shrubs such as willow, legumes, and grasses. Figure 2 shows a typical section. Trees along the stream would be selectively thinned to remove dead vegetation and to provide aesthetic benefits. The

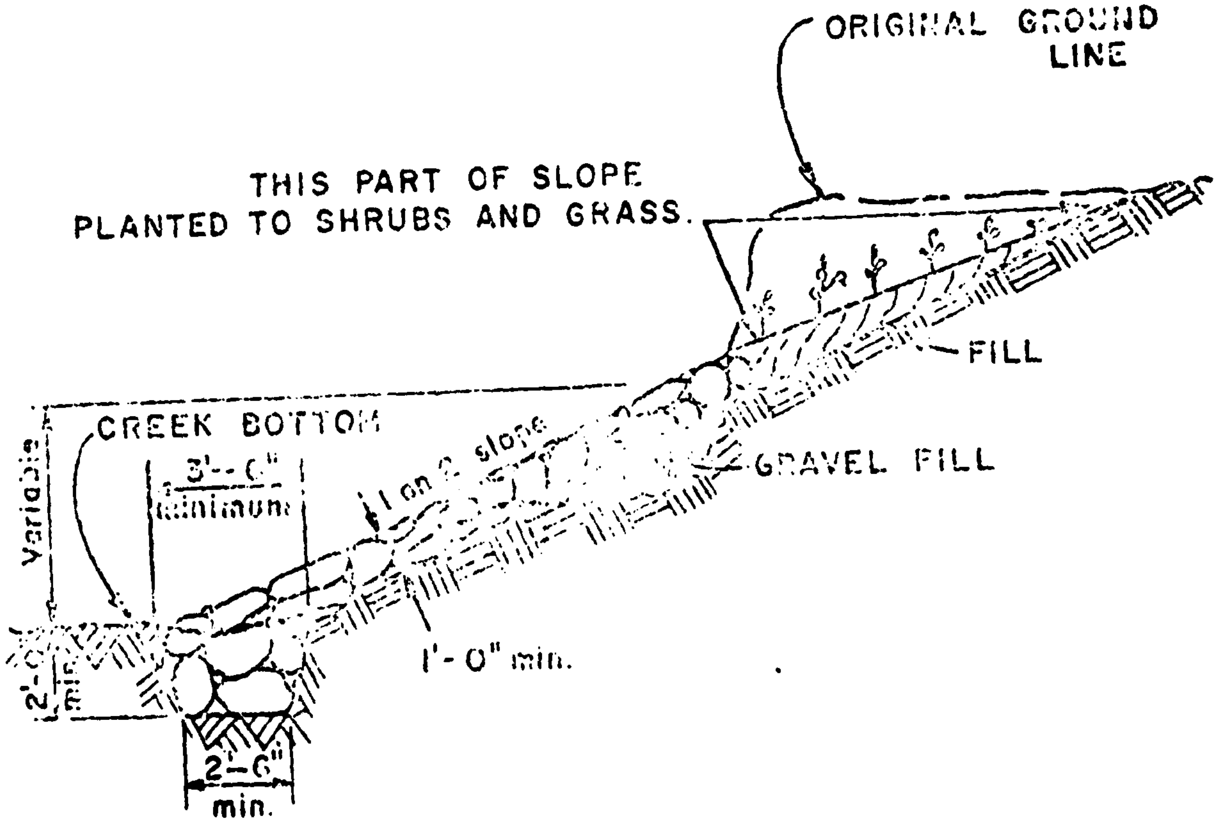

Figure 2. Sketch of Typical Rip-rap Section

channel alignment would not be altered. Such an approach has proved to be successful on Buffalo Creek, N.Y., where the bank treatment fits in well with the natural settings of the stream.

The general reaches which would require bank treatment are from river miles 13.6 to 19.3, miles 21.9 to 27.0, and miles 30.2 to 43.9. Another mile would be treated on the Little Cuyahoga River. This is a total of 24.5 river miles. The remaining 6.8 miles between Independence and Akron are essentially stable. There may already be adequately stabilized reaches in the 24.5-mile sections, but it has been assumed that there are none.

The SCS survey of bank erosion which was made in 1951 and 1952 showed that 36% of the river mileage in the unstable reaches was eroding. However, it is assumed that the revetments themselves would have to be more continuous and have sufficient length to be protected against erosion at both the upstream and downstream ends. A more realistic estimate of the needed revetment mileage is 67% of the river mileage. Only eroding banks would be revetted, and depositional banks would be left alone. Based on these assumptions, the total length of revetment would be about 77,000 feet. The typical cross-section, the height of which is based on the SCS damage survey, would contain 31 square feet of cross-section, leading to a required rock volume of 100,000 cubic yards.

The cost and annual charges are indicated in Table VI.

Some Design Considerations

In carrying out channel stabilization work on the Cuyahoga, it is necessary to compensate for the load which the stream will either be

Table VI

Bank Stabilization Costs and Charges

A. Costs

Item	Amount
Revetment ($15/cu. yd.)	$1,500,000
Upper bank thinning and beautification ($10,000/mile)	245,000
Subtotal	$1,745,000
Add 25% Contingencies	436,000
Total	$2,181,000
Say $2,200,000	

B. Annual Charges

Item	Amount
Interest	$121,000
Amortization (50 yrs.)	8,900
Maintenance (2%/yr.)	44,000
Average Annual Charge	$173,900

deprived of or will be added to it. If the floodplain is aggrading then the capacity of the stabilized reach must be increased over the original capacity of the unstabilized channel. In that way the additional load can be carried without causing deposition within the stabilized section.

Because aggradation is a temporary and usually culturally reduced phenomenon, it is probably better to control the source of the extra sediment than to try to stabilize the channel grade for a long time period. On the other hand, with stabilization of a degrading reach, less sediment will be produced and carried than before stabilization, and less transporting capacity will be needed to move the sediment in a reach. As an approximation, the transporting capacity per unit width, g_s, is proportional to water discharge per unit width of the stream multiplied by the stream slope raised to the 3/2 power. Whether or not the stream transports at this rate, let us assume that the actual transport rate does depend on this relationship. The slope which will be needed after stabilization, S_2, is therefore, approximately given by:

$$\left(\frac{S_2}{S_1}\right)^{3/2} = \frac{g_{s_2} \cdot q_1}{g_{s_1} \cdot q_2} \quad \ldots\ldots\ldots\ldots \quad (14)$$

in which S_1 = stream slope before stabilization, $g_{s_2} = g_{s_1} - \Delta g_s$ = load per unit width carried after stabilization, g_{s_1} = load per unit width carried before stabilization, Δg_s = change in load as a result of stabilization, and q_2, q_1 = water discharge per unit width after and before stabilization.

Since at the upstream end of a project the load will not vary due to stabilization, there will be no slope change, if changes in discharge with time are neglected. At the lower end of a reach the maximum slope change will occur. Each part of the stream would have to be analyzed with respect to the load passing through it and the maximum anticipated slope change calculated. Bed control sills would be installed and the toe of revetment placed well below the anticipated degradation level.

Because changing runoff conditions within the watershed may produce ever-increasing discharges, the maximum discharge change which is anticipated over the project lifetime ought to be included in the calculations.

Analysis of Benefit/Cost Ratio

A number of possible benefits have been outlined and will be considered in more detail here. They include benefits to navigation, increased water quality, land conservation, better fish habitats, increased recreational opportunities, flood control, and aesthetic benefits.

A. Reduction in Harbor Dredging. - The proposed stabilization work would essentially eliminate production of channel sediments from 30.6 miles on the main stem and an additional mile on the Little Cuyahoga. Let us assume, for lack of better information, that the production figure of 40,000 tons/yr. is realistic and that amount would be eliminated from entering the harbor. A benefit will result from having less sediment to dredge in order to maintain the depths required for navigation in the harbor.

It is assumed that over the project life of 50 years the dredged material will be placed in diked disposal areas for 5 years and open-lake dumped for 45 years. In the First Interim Report, diked disposal was

given as \$4.66/cu.yd. Updating this figure to 1972 by using the Engineering News-Record (ENR) Construction Price Index gives a cost of \$5.16/cu.yd. Open-lake dumping in 1967 cost \$1.04/cu.yd. for quantities in excess of 340,000 cu. yd. For lesser quantities, the cost ranged up to \$1.20/cu.yd., so the \$1.04 represented the lowest cost. By the ENR Index this cost would now be \$1.68/cu.yd. However, open-lake dumping would begin only after 5 years. It is assumed that this cost would rise by 6% a year for five years, to give a cost of \$2.26/cu.yd. Since the Construction Price Index has risen at a rate of over 10% compounded per year for the past five years, that projected cost could be too low.

Based on diked disposal at \$5.16/cu.yd. for 5 years and open-lake dumping at \$2.26/cu.yd. for 45 years of 74,000 cu. yds., the cost savings would be \$9,435,000, or an average annual savings of \$189,000. Solely on the basis of cost savings on dredging the benefit/cost (B/C) ratio exceeds unity (1.09).

B. Water Quality. - A reduction in sediment production will decrease the sediment concentration in the stream. An increase in water quality will decrease the costs of water treatment in municipal governments and to industries. These costs are related to the cost of cleaning sediment from equipment, the cost of filtration, and the cost of maintaining filtration equipment. Sediment causes wear to pumps and requires extensive pretreatment of water to make it suitable for use. Since almost all bank erosion occurs during high flows and periods of ice damage, the reductions in concentration would occur at intervals of time when higher flows pass through and would not be a constant reduction.

If it is assumed that the reduction in sediment produced will be proportioned among suspended and unmeasured load according to the previous estimates that at Independence 43,000 tons/year of suspended load were derived from channel erosion and 155,000 tons/year of unmeasured load were derived from the channel, then due to the revetment work the suspended sediment load at Independence would be diminished by 40,000 x 43,000/198,000 tons/year, or 8,700 tons/year. The percent reduction would be equal to (8,700/211,000) x 100 = 4%. The unmeasured load would be reduced by about 20%. This analysis does neglect the possibility that stabilization would stop the erosion of the 30% fraction of the bank material which is colloidal.

Based again on the SCS Survey Report, where that proposed program would reduce streambank erosion by 5.1% and sheet erosion by 53.1%, leading to a net reduction of 99,300 tons/year, the considered bank revetment would affect industrial water supplies to a smaller extent, (40,000/99,300) x 9.1, the last figure being the percent reduction in damages due to the SCS program. The revetment, therefore, could reduce damages to industrial water supplies by about 3.7%. Damages in 1950 were assessed at $111,000. Updating by the ENR Index would convert these to $372,000 in 1972 cost levels. The benefits would then be $14,000 on an average annual basis.

C. Navigation. - Besides the reduction in dredging costs, which have already been assessed, there are other cost reductions possible due to lower sediment production. Since the material derived from channel erosion is coarse-grained, it will settle out first in the upstream end of the navigation channel. Dredging costs are actually higher for that material

since hauling costs are longer, and smaller equipment must be used on account of the narrowness of the channel.

In addition, boats must use additional time to maneuver around the dredging equipment and are exposed to additional hazards. A reduction in sediment deposited in the harbor means that navigation depths can be maintained easier and there will be less loss of income due to light loading, less damage to boats from the deposits, and less costs in using additional tugs to assist boats in the shallow channel.

In the SCS Survey Report of the watershed of 1952 these additional damages were estimated to equal 64 percent of the dredging costs. If this proportion is applied to the dredging cost savings, an additional benefit of $120,000/year would accrue to navigation uses of water.

D. Land Conservation. - Streambank erosion causes the loss of slightly more than two acres of land each year in the reach under consideration. This is due to the shifting of the meander pattern. On the other hand, deposition on point bars does create new land. However, this newly created land is essentially infertile and must be treated before it can be used productively. Since the creation of topsoil and grading of land is a long-term and expensive proposition, it is assumed that the cost of reclaiming this newly created land is equal to its value. A net loss will result in the erosion of the presently productive land.

For want of accurate figures it is assumed that the net loss in value will be $1,000/acre, and the loss in usefulness will be $100/acre. The loss in taxes due to erosion will not be estimated. An additional cost, not easily evaluated, is that of resurveying property boundaries and governmental boundaries which are defined by the course of the river.

Therefore, the net annual loss due to land erosion will be assessed as \$2,200.

A question which ought to be asked at this point is what degree of freedom to meander should be allowed the river at this point in time. The public must decide whether it is more valuable to control the channel or to allow it to follow its natural behavioral tendencies. This question is strongly linked with what kind of river and floodplain the public prefers, and with the value of floodplain land within the entire framework of urban land use.

E. Fish Habitats. - The spawning grounds of game fish could be improved since the bottom of the channel would tend to sort out the finer material and leave coarser grained sediments. Less fines would be present in the water itself. Improvements in species and species production might result. The removal of snags and fallen trees could alter the habitats adversely, but pools at bends would deepen. Specific improvements designed to enhance habitats could be included in the project. A nominal amount of \$500 is estimated as a benefit to fishermen.

F. Recreation. - The improvement in the river and its immediate surroundings would permit the greater development of active and passive recreation. Should the flood plain lands of the river be incorporated into a park system the recreation benefits of bank stabilization would be significant. At this time it is estimated that active and passive use would increase by 5,000 day-users at \$1.00 each without further inclusion in a park system.

G. Flood Control. - Although flood control is not a goal under consideration, the revetment of banks would decrease channel roughness and

increase the cross-sectional area by a few percent. This could be sufficient to drop the stages due to the Intermediate Regional Flood by about 1' to 2' in some treated areas. Benefits would accrue to property owners, transportation facilities, and governments. Although stage-damage curves have not been prepared, benefits have been estimated in proportion to the reduction in stages computed in the SCS Survey Report at $2,400 annually.

H. Aesthetic Benefits. - By proper treatment of the work with due respect for natural beauty, substantial aesthetic benefits could arise. The stabilization of eroding banks would also control erosion of the clay fraction, which amounts to 30% of the total, leading to clearer water in the stream. The reduction in muddiness would not be complete, since other tributaries feed colloids in from bank erosion, and other such material comes in from soil erosion on the watershed. The aesthetic benefits are nominally estimated at $10,000/year based primarily on the large number of persons estimated to come in visual contact with the project who would be more pleased with its appearance and consider it to have greater value.

Summary

The estimated benefits due to the outlined bank stabilization work are listed in Table VII. The total is $335,000. The cost of the work is outlined in Table VIII. These total $174,000, yielding a benefit/cost ratio of 1.9:1.0.

A benefit/cost ratio of about 2:1 has been derived from a preliminary evaluation of bank stabilization on the Cuyahoga River from Independence to Akron. Additional analysis is recommended and should include the

following criteria:

a. More structural devices to better fish and wildlife habitats should be incorporated. Some of these devices are pictured in Figures C-2 and C-3 of the First Interim Report.

b. Th work should be considered as part of a total system of flood-plain use, including possible parks and recre tional uses.

c. The incorporation of a minor amount of flood control capability into the improvements should be considered.

Table VII

Estimated Benefits from Bank Stabilization

(1) Benefit Category	(2) Average Annual Benefit
A. Dredging	$189,000
B. Water Quality	14,000
C. Navigation	120,000
D. Land Conservation	
a. Land value	2,000
b. Land use	200
E. Fish Habitats	500
F. Recreation	5,000
G. Flood Control	2,400
H. Aesthetic	10,000
Total Benefits	$335,000

Table VIII

Estimated Costs of Bank Stabilization

(1) Item		(2) Amount
A. Project Cost		$2,200,000
B. Annual Charges		
a. Interest		121,000
b. Amortization		8,900
c. Maintenance		44,000
Total		$173,900
Say		$174,000
C. Benefit/Cost Ratio	=	1.9:1.0

CONCLUSIONS

Preliminary estimates of the sediment production from the Cuyahoga River basin indicate that about 370,000 tons/year of sediment pass the stream gage at Independence. The reach of the river between Independence and Old Portage is considered to be a major source of sediment, but the exact magnitude is as yet unknown. A number of methods for estimating sediment production from various sources has been outlined and orders of magnitude have been developed, but the major problem of how much sediment is coming from each source is unsolved. The feasibility of bank stabilization work between Independence and Old Portage has been demonstrated.

Additional studies of the erosion and sediment problems in the basin need to be performed. These are listed in the next section.

FUTURE STUDIES

The studies to be made in the future should delineate as precisely as possible the production of sediment from various parts of the basin and the rates of change of production with changing population and land use patterns. Various restorative measures should be studied and their application costs determined. The effectiveness of these measures and the resulting changes in the character of the river and its water quality should be predicted. This process would lead to a number of alternatives which can be presented to the public for their decision on further implementation of restorative measures. Based on costs, expected effectiveness, and future changes, sound decisions can be made.

In the basin sediments are primarily derived from soil erosion and channel erosion, due to natural processes and the pressure of agricultural and urban activities. A number of general studies are required with respect to land use and population changes. Other studies are needed to deal with land and channel erosion.

A. Land Use and Population Changes

1. Basin water balance. Is water being imported in significant amounts from outside the basin?
2. What are the population growth rates and rates of urbanization in various parts of the basin?
3. What have been the changes in runoff coefficients, unit hydrographs, and peak discharges in past years?
4. What is the influence of the spatial and temporal alteration of water flows by the Akron sewage treatment plant?

5. What is the sediment production rate due to construction?

6. Refine total load production analyses made in this paper.

B. Land Erosion

1. Review the soil loss estimates made by the SCS and the NEOWDP for the several parts of the basin.

2. Existing reservoir survey data and measurements of sediment accumulation in farm ponds, debris dams, and other sites should be assembled and analyzed.

3. Critical soil loss areas should be identified and treatments suggested.

4. Determine the effects and costs of applying treatments. Who will pay for this?

5. What effect will the erosion control ordinances have on sediment yield?

6. Survey all gravel pits and extraordinary construction activities. Estimate production and the cost of treating each site. Where will these funds come from?

C. Channel Erosion

1. From series of aerial photos and topographic maps determine migration rate of stream channels in basin where possible. Identify critical areas.

2. Using other historic data, such as newspaper accounts of stream and river behavior and old surveys, estimate volume changes and floodplain degradation rates.

3. Study channel regime and the influence of changing discharge patterns as a means of estimating sediment production in

stream channels.

4. Take samples of bed and bank materials throughout channels. Cross-sections should be measured and stream slopes surveyed. Rates of bank-cutting should be calculated and checked against previous measurements. Possible heavy mineral analysis for determining relative discharge amounts.

5. Analyze channel stabilization measures with respect to cost and effectiveness.

D. Project Impact

1. Analyze environmental impact of project.

2. How is project planning influenced by regional and local land use planning?

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
975 West Third Avenue
Columbus, Ohio 43212

February 14, 1978

Mr. Donald M. Liddell
Chief, Engineering Division
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Sir:

The attached summaries of suspended sediment data collected during the period December 1976 through November 1977 are forwarded per agreement NCB-IS-77-06.

The collection of suspended-sediment samples was begun on a twice weekly basis on December 1, 1976 and stopped on November 30, 1977 except at Independence, Bedford, and Old Portage. The frequency of sampling was increased to three times daily during runoff events.

All suspended-sediment samples were depth integrated and collected at mid-point of flow, except during special sediment discharge measurements, by means of a U.S. DH-59 sediment sampler.

Special-sediment discharge measurements were made using the equal discharge increment (EDI) method. From these measurements it was determined that coefficients to correct sediment loads were not required. The depth integrated, mid-point of flow samples were representative of the sediment load carried by the stream.

To determine the suspended-sediment discharge, the concentration of each sample was plotted on a water-stage chart. Guided by these points and by gage-height observations, concentration and gage-height curves were drawn. Daily mean concentrations were determined from these curves. Daily sediment discharge, in tons per day, were computed by multiplying the product of the estimated daily mean water discharge and the estimated daily mean concentration by the conversion factor of 0.0027. These data are considered poor.

The daily sediment discharge at Old Portage, Bedford, and Independence were not estimated. These sediment discharges were determined from a continuous gage-height trace. These data are considered good.

Total suspended sediment discharge for the period December 1976 through November, 1977 are listed in table 1. Monthly sediment discharges are listed in table 3.

EXHIBIT E-2

Particle-size distribution of suspended sediment was determined by the sieve-bottom withdrawal tube method for one sample collected at each station on February 24, 1977 (see table 2).

Streamflow for the period was normal for December, deficient for January, normal for February and March, excessive for April, normal for May, below normal for June and July, and excessive for August, September, October and November.

Copies of station descriptions for the six temporary sites are attached.

This letter report completes our contractural obligations for agreement NCB-IS-77-06. Final billing will be mailed at a later date.

Sincerely yours,

David E. Click

David E. Click
District Chief

JWB/jw

Encl.

cc: Dick Aguglia, Buffalo District
Corps of Engineers

G. Francis

J. Klingler

TABLE 1

SUMMARY OF SUSPENDED SEDIMENT STATIONS

in the Cuyahoga River Basin

for the period December 1976 - November 1977

	Station	Drainage area (sq.mi.)	Water discharge (total cfs-days)	Sediment discharge (tons)	Sediment discharge (tons/sq.mi.)
04206000	Cuyahoga River at Old Portage	404	156,348	20,342	50
04206050	Mud Brook nr. Akron	29.3	13,360	7,820	267
04206220	Yellow Creek nr. Botzum	30.7	12,908	9,169	299
04206370	Furnace Run nr. Everett	17.7	6,797	9,665	546
04206400	Cuyahoga River at Peninsula	494	213,671	113,293	229
04206420	Brandywine Creek nr. Jaite	27.2	12,943	10,414	383
04206450	Chippewa Creek nr. Brecksville	17.7	7,740	5,984	338
04207200	Tinkers Creek at Bedford	83.9	46,002	28,657	342
04208000	Cuyahoga River at Independence	707	319,107	234,979	332

TABLE 2

PARTICLE SIZE DISTRIBUTION OF SUSPENDED SEDIMENT

STATION	DATE	TIME	percent finer than the size (in millimeters) indicated									
			.002	.004	.008	.016	.031	.062	.125	.25	.5	1.0
Cuyahoga River at Old Portage	2/24/77	1650	35	42	51	64	77	82	89	100		
Mud Brook near Akron	2/24/77	1150	24	31	40	55	73	82	88	96	100	
Yellow Creek near Botzum	2/24/77	1200	15	21	29	42	55	70	77	90	99	[illegible]
Furnace Run near Everett	2/24/77	1215	25	34	45	62	86	93	97	99	100	
Cuyahoga River at Peninsula	2/24/77	1600	20	30	41	55	77	86	92	97	100	
Brandywine Creek near Jaite	2/24/77	1630	38	50	61	77	88	95	97	100		
Chippewa Creek near Brecksville	2/24/77	1335	30	39	50	67	84	96	100			
Tinkers Creek at Bedford	2/24/77	1250	30	38	47	60	80	85	91	96	99	100
Cuyahoga River at Independence	2/24/77	1645	44	51	61	74	87	93	97	100		

TABLE 3

Monthly Summary of Suspended Sediment Stations

	04206000 Cuyahoga River at Old Portage		04206050 Mud Brook near Akron		04206220 Yellow Creek near Botzum	
	cfs-days	tons	cfs-days	tons	cfs-days	tons
December, 1976	7,407	204	1,335	172	1,288	63
January, 1977	5,059	93	415	16	550	13
February	15,107	3,925	2,027	3,555	1,992	3,663
March	36,135	4,260	2,771	1,517	2,622	2,186
April	22,324	1,910	1,904	1,170	2,033	2,537
May	9,873	324	580	42	652	35
June	7,358	1,550	474	138	470	142
July	7,030	1,751	583	546	470	63
August	10,762	2,696	564	83	285	30
September	8,808	909	874	288	634	107
October	8,751	428	525	58	475	12
November	17,734	2,292	1,308	235	1,437	318
Total	156,348	20,342	13,360	7,820	12,908	9,169

TABLE 3 - continued

Monthly Summary of Suspended Sediment Stations

	04206370 Furnace Run near Everett		04206400 Cuyahoga River at Peninsula		04206420 Brandywine Creek near Jaite	
	cfs-days	tons	cfs-days	tons	cfs-days	tons
December, 1976	589	22	12,098	571	765	110
January, 1977	224	1	7,843	357	190	6
February	1,159	5,090	23,211	30,800	2,789	3,850
March	1,615	2,264	49,551	30,424	3,924	2,965
April	1,055	1,651	32,882	19,092	1,471	1,479
May	413	26	12,193	1,372	400	275
June	287	224	7,372	2,413	219	54
July	286	161	9,169	1,602	385	620
August	183	7	12,775	4,418	421	95
September	247	40	12,123	4,307	628	212
October	221	7	11,612	719	396	82
November	518	172	22,842	17,218	1,355	666
Total	6,797	9,665	213,671	113,293	12,943	10,414

TABLE 3 - continued

Monthly Summary of Suspended Sediment Stations

	04206450 Chippewa Creek near Brecksville		04207200 Tinkers Creek at Bedford		04208000 Cuyahoga River at Independence	
	cfs-days	tons	cfs-days	tons	cfs-days	tons
December, 1976	750	16	2,060	298	14,053	1,229
January, 1977	236	4	2,291	92	11,728	593
February	1,126	1,738	7,859	8,060	38,891	55,298
March	1,567	1,264	10,027	6,175	73,943	68,795
April	977	1,348	6,335	3,562	47,311	34,953
May	489	7	1,550	197	15,862	1,825
June	449	277	1,326	2,834	10,731	6,869
July	594	1,082	2,113	2,931	16,150	12,390
August	150	3	3,765	1,790	24,909	22,941
September	173	21	2,148	772	17,510	9,752
October	160	3	1,446	173	15,684	1,092
November	769	221	5,082	1,773	32,335	19,242
Total	7,740	5,984	46,002	28,657	319,107	234,979

9-197
(Nov. 1954)

04206050
File No. { Wash. ... Field ...

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Description Prepared 12-10-76
(Date)
by J. H. Klingler

Description of Gaging Station on Mud Brook
near Akron, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A or 9-213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9-213C or 9-213H. Initial and date all sheets.)

Hydrologic Unit 04110002

Location.--Lat 41°08'20", long 81°32'54" in T.3N., R.11W., Summit County, at bridge on Akron-Peninsula Rd., 1.6 miles downstream from Little Cuyahoga River, 2.7 miles upstream from Yellow Creek, and 4 miles north of Akron.

To reach station from S.R. 8 in Cuyahoga Falls, drive west on Portage Trail for 2.3 miles to intersection with Akron-Peninsula Rd. Turn right (north) and proceed 0.1 mile to bridge and gage.

Established.--December 7, 1976 by J. H. Klingler and D.E. Thayer.

Drainage area.--29.3 sq. mi.

Gage.--Type A wire-weight gage is attached to the downstream side of the bridge.

Reference marks.--
R.M. No. 1, chiseled square on top of left downstream bridge abutment.
R.M. No. 2, chiseled square on top of right upstream bridge abutment.
See level summary for elevations.

Control and channel.--Submerged pipe just below bridge is control up to medium stages. Control and channel will freeze during the winter months.

Channel is control at high stages. It is straight above and below gage and will overflow during times of high water.

Discharge measurements.--Wading measurements during low and medium stages can be made at sections in the vicinity of the gage. High water measurements can be made from the upstream side of the bridge. Bridge is not marked and a tag line will have to be used for each measurement.

Floods.--

Point of zero flow.--

Winter flow.--Entire stream will freeze during extremely cold weather.

Diversion.--None.

Regulation.--Some regulation by ponds in the upper part of the basin.

Accuracy.--Fair data can be collected except during the winter months which will be poor.

Cooperation.--Corps of Engineers, Buffalo District.

9-177
(Nov 1970)

04206220

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File No. { Washington .... / Field ....

Description Prepared 12-13-76 (Date)

by J.H. Klingler

Description of Gaging Station on Yellow Creek

nr. Botzum, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9 213A or 9 213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9 213C or 9 213H. Initial and date all sheets.)

Hydrologic Unit 04110002

Location.--Lat. 41°09'47", long 81°35'02", in T.3N., R.11 W., Summit County, at bridge on Bath Rd., 2.7 miles downstream from Mud Brook, 4.2 miles upstream from Furnace Run and 0.5 west of Botzum.

To reach station from S.R. 303 in Peninsula, drive south on Riverview Rd. 6.1 miles to Bath Rd. Turn right (west) and proceed 0.4 to bridge and gage.

Established.--December 7, 1976 by J.H. Klingler and D.E. Thayer.

Drainage area.--30.7 sq. mi.

Gage.--Type A wire-weight gage is attached to the downstream side of the bridge.

Reference marks.-- R.M. No. 1, chiseled square on top of left downstream bridge abutment.
R.M. No. 2, chiseled square on top of right upstream bridge abutment.
See level summary for elevations.

Control and channel.--Riffle just below gage is low water control. It is composed of gravel and cobbles and is subject to collection of leaves and debris. Channel is control for medium and high stages. It is straight above and below gage. Both banks are high and brush covered and will overflow only during times of extremely high stages.

Discharge measurements.--Wading measurements during low and medium stages can be made in the vicinity of the gage. ~~High water measurements can be made in the vicinity of the gage.~~ High water measurements can be made from the downstream side of the bridge. Bridge is not marked and a tag line will have to be used for each measurement.

Floods.--

Point of zero flow.--

Winter flow.--Entire stream will freeze during the winter months.

Diversion.--None.

Regulation.--None.

Accuracy.--Fair data can be obtained except during the winter months which will be poor.

Cooperation.--Corps of Engineers, Buffalo District.

c 4/2000 470
04-04270

9-97
(1974)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File No. { Washington .... Field ....

Description Prepared 12-14-76 (Date)
by J.H. Klingler

Description of Gaging Station on Furnace Run

nr. Everett, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A or 9-213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9-213C or 9-213H. Initial and date all sheets.)

Hydrologic Unit 04110002

Location.--Lat 41°12'28", long 81°35'07", in T.4N., R.11W., Summit County, at bridge on Wheatley Rd., 4.2 miles downstream from Yellow Creek, 2.9 miles upstream from Salt Run and 0.7 mile west of Everett.

To reach station from S.R. 303 in Peninsula, drive south on Riverview Rd. for 2.9 miles to Everett Rd. Turn right and proceed 0.6 mile to Wheatley Rd. Turn right and continue 0.3 mile to bridge and gage.

Established.--December 7, 1976 by J.H. Klingler and D.E. Thayer.

Drainage area.--17.7 square miles.

Gage.--Type A wire-weight gage is attached to the downstream side of the bridge.

Reference marks.--R.M. No. 1, chiseled square on top of right upstream bridge curbing. R.M. No. 2, chiseled square on top of left downstream bridge and curbing. See level summary for elevations.

Control and channel.--Riffle just below bridge is low water control. It is composed of gravel and small rocks and is subject to collection of leaves and debris.

Channel is control for medium and high stages. Left bank is high and will not overflow. Right bank will overflow at high stages.

Discharge measurements.--Wading measurements during low and medium flow can be made in the vicinity of the gage. High water measurements can be made from the downstream side of the bridge. Bridges is not marked and a tag line will have to be used for each measurement.

Floods.--

Point of zero flows.--

Winter flow.--Stream will freeze during the winter months.

Diversion.--None.

Regulation.--None.

Accuracy.--Fair data can be obtained except during the winter months which will be poor.

Cooperation.--Corps of Engineers, Buffalo District.

9-197
(Rev. 1964)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File No. 04206425
Description Prepared 12-21-76 (Date)
by J.H. Klingler

Description of Gaging Station on Brandywine Creek at Jaite, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A or 9-213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9-213C or 9-213H. Initial and date all sheets.)

Hydrologic Unit 04110002

Location.--Lat 41°17'09", long 81°33'44", in T.5N., R.11 W., Summit County, on left bank 50 feet downstream from bridge on private road, 2.1 miles downstream from Spring Run, 3.3 miles upstream from Chippewa Creek and 0.6 mile east of Jaite.

To reach station from S.R. 82 in Brecksville, drive south on Riverview Rd. for 2.7 miles to intersection of Highland Rd. at Jaite. Turn left (east) on Highland Rd. and proceed 0.4 mile, across Cuyahoga River, to first road on the right. Turn right and continue 0.3 mile to station. This road is on the property of the Tecumseh Corrugated Box Co. Permission has been given by the company to use the road for access to the station.

Established.--December 7, 1976 by J.H Klingler and D.E. Thayer.

Drainage area.--27.2 sq. mi.

Gage.--Staff gage in two sections. Low and medium water, 0.0 to 6.7 fastened to tree on left bank 50 feet downstream from bridge.

High water, 6.8 to 10.1 fastened to large tree on left bank, 50 feet downstream from bridge and 25 feet from edge of water.

Two crest stage gages are attached to the bridge. One on the upstream side of the bridge and one on the downstream side.

Reference marks.--R.M. no. 1, chiseled square on top of left downstream bridge abutment. Elev = 10.816
R.M. No. 2, chiseled square on top of right downstream abutment. Elev. = 10.794
See level summary for elevations.

Control and channel.--Riffle approximately 50 ft. below gage is control for low and medium stages. It is composed of rocks and is subject to collection of debris and leaves. Channel is control for high stages. Both banks will overflow during high water.

Discharge measurements.--Wading measurements during low and medium stages can be made in the vicinity of the control. High water measurements are not possible due to the culvert type opening at the bridge and the absence of handrails for supporting bridge measuring equipment. High water discharges will have to be estimated by indirect methods. At each visit to the station when wading measurements are not possible, a tape down from the top of each crest stage gage plus a staff gage reading is essential. If possible, 3 or 4 velocity readings of the flow through the culvert type bridge opening at downstream end could be quite helpful in computing the flow.

Floods.--

Point of zero flow.--

Winter flow.--Channel above control will freeze during the winter months. Control will freeze during periods of extremely low temperatures.

Diversion.--None

Regulation.--None

Accuracy.--Good data can be obtained during the low to medium flow conditions. High flow will be poor.

Cooperation.--Corps of Engineers, Buffalo District.

9-207 (Nov 1964)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

04206450

File No. { Washington .... / Field ....

Description Prepared 12-22-76 (Date)

by J.H. Klingler

Description of Gaging Station on Chippewa Creek

near Brecksville, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A or 9-213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9-213C or 9-213H. Initial and date all sheets.)

Hydrologic Unit

Location.--Lat 41°19'02", long 81°35'32", in T.5N., R.12W., Cuyahoga County, at bridge on Riverview Rd., 3.3 miles downstream from Chippewa Creek, 4.6 miles upstream from Tinkers Creek, and 1.5 miles east of Brecksville.

To reach station from the intersection of U.S. 21 and S.R. 82 in Brecksville drive east on S.R. 82 1.9 miles to Riverview Rd. Turn right (south) and continue 0.4 mile to bridge and gage.

Established.--December 29, 1976 by J.H. Klingler.

Drainage area.--17.7 sq. mi.

Gage.--RP chiseled in center of downstream handrail. A tapedown from this RP is used for obtaining water elevations.

Reference marks.--R.M. No.1, chiseled square on top of right upstream abutment. R.M. No. 2, chiseled square on top of left downstream abutment. See level summary for elevations.

Control and channel.--Riffle just below bridge is low water control. It is composed of small rocks and gravel. It is subject to collection of leaves and debris, and will freeze during the winter months.

Channel is control at medium and high stages. Both banks will overflow at high stages.

Discharge measurements.--Wading measurements during low and medium flow can be made in the vicinity of the bridge. High water measurements can be made from the downstream side of the bridge. Bridge is not marked and a tag line will have to be used for each measurement.

Floods.--

Point of zero flow.--

Winter flow.-- Stream will freeze during the winter months.

Diversion.--None.

Regulation.--None

Accuracy.--Fair data can be obtained except during the winter months which will by poor.

Cooperation.--Corps of Engineers, Buffalo District.

9-197
(Nov. 1954)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

~~04206200~~

File No. Washington ......
Field ....

Description Prepared 12-27-76
(Date)
by J. H. Klingler

Description of Gaging Station on .... Cuyahoga River ....

at Peninsula, Ohio

(Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A or 9-213E for cross section. Use second page of this form for sketch if room is available, otherwise use Form 9-213C or 9-213H. Initial and date all sheets.)

Hydrologic Unit 04110002

Location.--Lat 41°14'29", long 81°33'00", in T.4N., R.11 W., Summit County, at bridge on S.R. 303 in Peninsula, 3.9 miles downstream from Furnace Run and 5.1 miles upstream from Brandywine Creek.

To reach station from the intersection of S.R. 8 and S.R. 303, drive west on S.R. 303 for 3.4 miles to bridge and gage in Peninsula.

Established.--November 18, 1976 by J.H. Klingler and R.E. Horky.

Drainage area.--494 sq. mi.

Gage.--Type A wire-weight gage is attached to the downstream side of the bridge.

Reference marks.--R.M. No.1, chiseled square on top of right upstream wingwall. R.M. No. 2, chiseled square on top of left downstream wingwall. See level summary for elevations.

Control and channel.--Riffle just below bridge is control for low stages. It is composed of large rocks. Channel is control for higher stages. It is straight above and below bridge. Both banks are high and should not overflow.

Discharge measurements.--Wading measurements during low water can be made in the vicinity of the bridge. Medium and high water measurements are made from the downstream side of the bridge. Bridge handrail is not marked and a tag line will have to be used for each measurement.

Floods.--

Point of zero flow.--

Winter flow.--Ice should not be a factor at this station.

Diversion.--Natural flow of stream is affected by diversions, storage reservoirs and power plants. Some diversion from the Tuscaravas drainage into this basin at Portage Lakes.

Accuracy.--Fair data can be obtained.

Cooperation.--Corps of Engineers, Buffalo District.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

IN REPLY REFER TO:

East Lansing Area Office
Manly Miles Building, Room 202
1405 South Harrison Road
East Lansing, Michigan 48823

December 6, 1978

Colonel Daniel D. Ludwig
U.S. Army Engineer District
Buffalo
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Ludwig:

This planning aid letter for the Cuyahoga River Restoration Study provides a general overview of the fish and wildlife resources of the study area and a preliminary assessment of the study to date. It also expresses concern about the potential impacts of some of the proposed erosion control alternatives, and offers suggestions about the direction of the study.

This letter has been prepared under the authority of, and in accordance with, provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.).

The Cuyahoga River Restoration Study was authorized by the Flood Control Act of 1968 (Section 219). Subsequently, due to adverse public reaction at the initial public meeting in 1970, the scope of the study was expanded in response to Section 108 of the 1970 Flood Control Act.

At an August 1976 coordination meeting, there was consensus among agencies that the most critical remaining study objective was the identification and control of the more prolific sources of sediment entering the Cuyahoga River system (sheet and gully erosion). Under the current study, sediment source identification was undertaken by the U.S. Soil Conservation Service (SCS). Based on their data, the Corps of Engineers will develop alternative erosion - sedimentation control measures. The SCS data initially indicated that a substantial portion of the stream sediment load is generated from streambank erosion. Specific erosion problem areas have been identified on the Cuyahoga River mainstem and its tributaries. We understand that further analysis also indicates heavy sediment loads are produced by upland sheet and gully erosion.

The U.S. Fish and Wildlife Service has reservations about the methodology used in determining sediment source data in this study. It is our understanding that the Cuyahoga River tributaries were sampled to determine the major contributors of

sediment to the mainstem. Randomly selected areas were sampled and run through the Universal Soil Loss Equation to estimate the amount of soil lost from a given area over a long period of time. We have not seen any attempt to determine the sediment transport routes or sediment delivery rates to the streams from the erosion problem areas. We believe such data is of utmost importance in developing effective sediment reduction alternatives. If sediment delivery rates were determined, high sediment source areas, i.e. critical erosion areas, could be identified. We suggest that perhaps only the critical areas in one or two watersheds should be treated for erosion control and subsequently monitored to determine the effectiveness of the control measures. If the control measures produce noticeable sediment reductions in several watersheds, there may be increased public interest in establishing erosion controls on private land holdings basinwide.

Your staff has not as yet had an opportunity to provide us written notification of the various alternative erosion control measures under consideration. We have been informed, however, that there are about five or six structural and nonstructural alternatives being developed. Measures proposed for upland areas which would probably be implemented by the SCS include revegetation and terracing. The Corps would treat the mainstem and tributary problem areas with riprap, channel alterations and the establishment of vegetation. Some areas would be treated with a combination of various alternatives.

Only a "windshield survey" of the erosion problem areas has been undertaken to date. Site specific fish and wildlife data cannot be obtained until we have additional maps specifically identifying the problem areas. We currently have maps which show problem areas on the Cuyahoga River mainstem only.

Generally speaking, basin wildlife habitat is in good supply. Much of the area is characterized as mixed rural-suburban. Undeveloped land outside the boundaries of the Cuyahoga Valley National Park will no doubt be ultimately developed for residential, commercial, or industrial purposes. Currently, however, the land is undergoing vegetation succession and, as such, provides diverse wildlife habitat. Non-game, small game and furbearer species are present and their populations will probably maintain themselves and, in some cases, increase. Consumptive wildlife utilization is minimal since hunting is prohibited in most of the study area. Nonconsumptive use will probably increase in the future. Utilization, however, is not the only value of wildlife. The quality of life in an area is determined in large degree on the presence of diverse, healthy wildlife populations.

Fisheries data for the Cuyahoga River system is more readily available than wildlife data. Several recent studies, if used as complementary information sources, can provide at least a general indication of the status of basin fisheries. These survey studies, however, have limitations as far as their usefulness in evaluating alterations of habitat conditions at specific sites. Once specific river or stream reaches have been selected as problem areas by the multiagency study team, we recommend that site specific fisheries data be obtained through an intensive sampling program. The sampling data should be closely coordinated with the Ohio Department of Natural Resources, Akron District Office, to ensure that

threatened or endangered species are not adversely affected by any of the proposed erosion control measures. Five species of fish on the state list of threatened or endangered fish have been identified within the Cuyahoga River system.

As part of this study, the SCS in coordination with U.S. Fish and Wildlife Service and the Ohio Department of Natural Resources plans to undertake habitat evaluations to determine the potential impacts of the proposed control measures on basin wildlife resources. We see excellent potential for increasing the quality of wildlife habitat through the utilization of grasses, shrubs, and herbaceous vegetation for erosion control. This vegetation would provide food, cover, and travel corridors for wildlife. As a multiagency effort we should give consideration to establishing permanent protection to some of the vegetative plantings in the future. Such protection may be effected through close cooperation with local units of government via zoning restrictions.

We have discussed the proposed habitat evaluations with the Ohio Division of Wildlife, Akron District Office, and share a concern that the evaluations may not be based on appropriate wildlife indicator species. We are skeptical of the selection of bobwhite quail as such an indicator since the Cuyahoga River area is at the northern edge of its range. Ruffed grouse would likewise be unsuitable since the area is at the western and southern edge of this species' range. We suggest that perhaps the cottontail rabbit and several non-game mammals and songbirds might be more indicative of the current wildlife habitat and the potential impacts of the alternatives on wildlife.

Based on discussions with your staff regarding the proposed alternative erosion control measures, we look favorably on the study's direction. For the most part, we would support the use of non-structural control measures. The following discussion briefly describes our views of some of the proposed alternatives.

In upland areas, we would favor the establishment of vegetative ground cover, providing existing vegetation is not severly altered. Our major objection to this alternative is that a monotypic environment could result. Although we believe the possibility of this occurring is remote, we want to take this opportunity to recommend the use of a variety of vegetation which would contribute to increased wildlife diversity. Good habitat interspersion could be created in the process of stablizing erodible soils.

For controlling streambank erosion we recommend bank stabilization through the establishment of vegetation. Our second preference is the utilization of natural rock or boulder riprap materials.

The U.S. Fish and Wildlife Service does not unconditionally endorse the extensive use of rock riprap. The erosion control benefits of riprap are recognized by the Service, but we urge the Corps to give consideration to existing habitat conditions in developing any proposal to use riprap. Although riprap may create fisheries habitat in some areas or under certain conditions, in other instances it may eliminate habitat. For instance, habitat is lost if riprap replaces undercut streambanks. Undercut banks provide excellent fish cover and should be retained wherever possible. Extensive reaches of riprap also eliminate the use of streambanks by furbearers (muskrats and beavers) and other bank dwellers such as

crayfish, reptiles and amphibians. Shorebirds which use streambanks and shallow waters as feeding and resting areas cannot use riprapped streambanks very effectively. In addition, the actual installation of riprap often results in the loss of riparian vegetation. Ironically, streambank disturbance from riprap installation could create considerable erosion and sedimentation, precisely what the study is designed to reduce.

Early study discussions touched on the possibility of altering streambed characterisitics such as gravel or boulder bars in order to redirect the flow of water away from highly erodible banks. Such a proposal causes us much concern since these areas, if there is sufficient water depth, provide spawning habitat for some species during the spring and summer months. Further, if such alterations occur, the whole regime of the stream is generally altered downstream and possibly upstream as well. Streambed alterations may not only adversely affect fishery habitat conditions in a considerable length of stream but may also shift the erosion problem to other streambank areas.

In summary, the U.S. Fish and Wildlife Service remains optimistic about the study's potential for erosion and sediment reduction and habitat quality improvements. We believe it essential, however, that extreme caution be exercised in developing the recommended alternatives to ensure compatibility with fish and wildlife requirements. Control measures such as stream meander removal, streambed alteration, or extensive streambank alteration would be viewed unfavorably by the Service since the potential adverse impacts are so great. The alternatives selected should be based on a multiagency analysis incorporating multi-objective planning.

In some locations, it may be necessary to compensate for project-induced changes to either fisheries or wildlife habitat where tradeoffs are unavoidable. Site specific fish and wildlife data must be obtained before such determinations can be made.

Responsiblity for coordination of this study under the Fish and Wildlife Coordination Act will be with our Columbus Field Office from this time forward. Our project files will be sent to them and we will provide them assistance as needed to ensure a smooth transition of project work.

We appreciated the opportunity to participate in such a project. We encourage the Corps to undertake similar environmental quality improvement projects within the Buffalo District.

Sincerely yours,

John Kopousky

Area Manager

cc: Regional Director, Twin Cities, MN(ES)
Columbus Field Office
Ohio Department of Natural Resources
Akron District Office, Ohio DNR

APPENDIX F

PUBLIC INVOLVEMENT

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

APPENDIX F
PUBLIC INVOLVEMENT

TABLE OF CONTENTS

Cuyahoga River Restoration Study

Summary Minutes of 15 November 1977 Meeting
of
Principal Study Participants

Medina, OH

A meeting was held on 15 November 1977 in Medina, OH to discuss the progress and direction of the Cuyahoga River Restoration Study (CRRS). The names of those persons in attendance are shown on the attached list. George Stem opened the meeting at approximately 10:00 a.m. by having the attendees introduce themselves. He then explained that the purpose of the meeting was to update the participants in the study and to discuss any problems concerning the study. A brief discussion of the Honey Creek study followed. This is part of the Lake Erie Wastewater Management Study. It was indicated that funds to implement land use programs to reduce sediment problems could possibly be obtained by local interests from EPA. This type of funds is not available from C. of E.

John Zorich outlined the present schedule for the CRRS indicating that the procedure in Principles and Standards would be used. The Plan of Study has been prepared which outlines the problems and course of action to be taken in the study and this is followed by a preliminary feasibility report which will address alternative solutions to the problems and recommend what alternatives require further detailed study. A final feasibility report would then be prepared which addresses in detail a few of the most promising alternatives. He then indicated that he feels the objectives of the sampling program were met in that the relative amounts of sediment transported by the tributaries of the Cuyahoga River have been determined.

Jim Board of the USGS presented the results of the nine month sampling period which indicated that the majority of sediment enters the main channel in the study area. A copy of the summary tables prepared by the USGS is attached. The estimated amounts of sediment from the tributaries was also presented. Jim explained that the present sampling program should not be continued beyond the 1 December 1977 contract period. He indicated that if better data is needed, automatic samplers should be used in order to obtain accurate data from run-off events. He stated that the cost to install the station would be approximately $30,000 and would cost about $15,000 to maintain annually.

William Hayes, Agronomy Specialist, from the SCS Lincoln, Nebraska office explained the program the SCS will be using to determine the amount of land erosion in the basin. He stated that there was a problem with the soil classifications in the Mud Brook (tributary to Cuyahoga River) data in that the same soil was classified in different

ways. The problem has been resolved and the computer printout should be completed within a few weeks. He explained that the soil losses determined in the program are based on long-term averages and not specifically for any certain year. Also, the actual amount of sediment delivered to the stream is determined by judgment rather than calculated techniques. Some environmental data is also being obtained in the inventory. This information will be used in determining the types of wildlife habitat in the basin. The main channel inventory will include the same type of information but will also include items such as estimated annual bank recession, bank height, etc.

Harvey Kananen stated that approximately 6 or 7 miles of the main channel (Cuyahoga River) inventory have been completed. It appears that the places where bank erosion occurs are located at the meanders and also are where some type of human activity such as powerline crossings or development adjacent to the stream has taken place. There is also a distinct lack of vegetation at the water line on the streambanks downstream of the Akron treatment plant. The amount of bank recession is being determined by comparison of aerial photographs, by discussions with local residents, and by vegetation on the banks.

There was some discussion on how the SCS will be able to separate the amount of sediment attributable to sheet erosion as compared to main channel erosion. It appears that this will be an almost impossible task to separate these items because of the many gullies and ravines running into the main stream in addition to the tributaries.

Jim Wade stated that he believes observations and judgment would be the most effective method to estimate the amount of in-stream erosion. The state-of-the art is not that precise to warrant increased sampling.

George Stem stated that in his opinion we have to deal with relative figures and not try to present information as being exact.

John Zorich stated he believes the present program is sufficient for the preliminary stage of the study and the SCS should be able to determine if more information is needed for the Final Feasibility Report. Bob Owens of the U.S. Fish and Wildlife Service stated his concerns for the project are primarily related to bank stabilization. He wanted to have someone from their office involved in field trips when specific areas and alternative plans are being considered. He also stated they would like a four season sampling program but does not have the manpower to do the sampling themselves. Therefore, they would have to work in conjunction with the State on this. Dave Kile stated he would like suggestions for improving habitat conditions from the F&WL Service during their field trips.

The meeting was adjourned at 3 p.m., and some of the participants visited the Chippewa Creek Watershed. Another meeting will be held in March 1978, and is scheduled for the 14th, 15th, or 16th. A meeting will also be held mid-June to discuss the draft Preliminary Feasibility Report due in July 1978.

Ralph Henry

RALPH HENRY
Project Manager

ATTENDANCE LIST FOR
15 NOVEMBER 1977 MEETING

NAME	ORGANIZATION
David Click	USGS, Columbus
James Board	USGS, Columbus
Jesse Klingler	USGS, Columbus
David Kile	SCS, Columbus
George Stem	SCS, Medina
Lavern Fusner	SCS, Columbus
William Hayes	SCS, Omaha, NB
Jim Wade	SCS, Columbus
Harvey Kananen	SCS, Medina
Jim Steiner	SCS, Medina
David Samples	SCS, Medina
Robert Owens	U.S. Fish and Wildlife Service, East Lansing
John Zorich	Corps of Engineers, Buffalo
Ted Yang	Corps of Engineers, NCD
Steve Yaksich	Corps of Engineers, Buffalo
Michael Pryor	Corps of Engineers, Buffalo
Ellen Cummings	Corps of Engineers, Buffalo
Ralph Henry	Corps of Engineers, Buffalo

Attachment 1

Cuyahoga River Restoration Study
Summary Minutes of 15 March 1978 Meeting
of
Principal Study Participants
Hospitality Inn, Cleveland, OH

Morning Session, 15 March 1978

A meeting was held on 15 March 1978 in Cleveland, OH, to discuss the progress and direction of the Cuyahoga River Restoration Study (CRRS). The names of those persons in attendance are shown on the attached list. Colonel Ludwig opened the meeting at approximately 9:30 a.m. by welcoming all meeting participants and stated that due to flooding on the Chagrin River he would have to leave at 12:00. Colonel Ludwig then stated that approximately 4 million cubic yards of material is annually dredged from harbors along the Lake Erie coast by the Federal Government at an annual cost of $9 million. Of this total, $2,400,000 is spent in dredging Cleveland Harbor and that reducing this cost is the reason for reducing erosion in the Cuyahoga River, if feasible. In addition to this annual cost for dredging Cleveland Harbor, $30 million has been spent to construct diked disposal sites since the material dredged from the harbor is not suitable for open lake disposal. The dike disposal sites are expected to be required for 10 years after which, due to reduction of point and non-point pollutants into the Cuyahoga River, the dredged material will again be suitable for open lake disposal. Colonel Ludwig also stated that even though the 2nd Interim Report of the Cuyahoga River Restoration Study concluded that no viable flood control project could be undertaken along the Cuyahoga River and its tributaries, it may be possible to undertake some minor flood control programs when we re-examine the flooding problem in the Final Report. Colonel Ludwig then turned the meeting over to John Zorich.

John Zorich stated that cooperation between the agencies involved in this study has been good and that the end result of this meeting today should be a clarification of the work required to complete the PFR and the FFR and their anticipated completion dates.

Dave Click stated that the U.S. Geological Survey has completed their portion of the study and provided the Corps with a data report outlining their findings. Mr. Click also stated that the results of this report are rough estimates of the sediments carried by the tributary streams and that his agency considers the data poor. For this reason, the results should be used as indicators only. Dave Kile, of the SCS, noted that according to the USGS report, approximately 75 percent of the

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sediment carried by the Cuyahoga River occurs during the months of February, March, and April. The meeting was then turned over to the Soil Conservation Service.

Mr. Robert Quilliam of the SCS stated that their investigation has brought to light results that were not expected when the study was begun. The SCS has currently completed 50 percent of the upland erosion inventory and seven miles of the Cuyahoga River streambank inventory. The Service's present thinking is to do detailed channel inventory on the main channel of two tributaries (Tinkers Creek and Chippewa Creek) and briefly look at the other four tributaries (Yellow Creek, Mud Brook, Furnace Run, and Brandywine Creek). The SCS will meet their time schedule of July 1978 for the Preliminary Feasibility Report (PFR) as outlined in the Interagency Agreement but this time schedule may have to be modified pending discussions on the required content of the PFR and Final Feasibility Report (FFR) to be held this afternoon.

George Stem stated that today we should decide which of the tributaries require 100 percent inventory along their main channels, discuss the schedule for the PFR and FFR and review the brochure and cassette presentations the SCS is preparing for their public involvement program. He then turned the meeting over to Harvey Kananen.

Harvey Kananen stated that the SCS has completed seven miles of the Cuyahoga River channel inventory but this information has not been coded for computer application. In addition to using the computer program to estimate channel erosion, Harvey has obtained four sets of aerial photographs which he will use to locate meanders that are forming on the main channel. From his investigation to date he has identified 11 major meanders which are located immediately below the 11 tributaries.

Harvey has done some hand calculations on the data collected to date on the Cuyahoga River channel. From these rough calculations it appears that this seven miles of main channel contribute 8,000 cubic yards of annual lateral recession. By pro rating this information to the entire 31-mile reach of the Cuyahoga River (for comparison purposes only), it would appear that as much as 55 percent of the sediment carried by the Cuyahoga River is from in-channel erosion, 45 percent is from upland erosion and 5 percent is from scour in the tributaries. At the present time it appears that the majority of the in-channel erosion of the river occurs at the meanders immediately below the tributaries. Heavy coarse material, carried by the tributaries, settles out in the river and forms relatively stable bars. Harvey conjectures that these bars probably divert the river flow against the opposite bank which causes the bank to erode. The SCS's current thinking is to prevent this material from entering the river and thus forming these bars. A major portion of the

SCS's investigation in the future will be to locate the source of this heavy coarse material. In addition to these gravel bars causing erosion, Harvey has identified debris bars which have formed on the river and which cause additional channel erosion. The SCS will probably recommend selective removal of these debris bars with annual maintenance being performed by various local interest groups. It was stressed that this postulation is highly speculative at this time, and further inventory and evaluation will be required by SCS before definitive conclusions are reached on the causes of heavy sediment loads in the lower Cuyahoga River.

Harvey then reviewed the SCS's upland erosion study. To illustrate their study, a computer printout of the Furnace Run watershed, using the Universal Soil Loss Equation (USLE) to estimate soil dislodgement, was briefly reviewed. From this printout it appears that woodland areas with high canopy (100 feet) and negligible undergrowth are the major sediment producing sources in the Furnace Run watershed. This finding came as a surprise to the SCS since for many years everyone thought that woodlands help prevent erosion. Some possible explanations as to why woodland areas are major sediment producing sources are: (1) the predominate species are tulip popular, ash, and maple whose leaves do not provide good ground cover since they deteriorate rapidly; (2) species such as hemlock and oak, whose leaves do not deteriorate rapidly, have been selectively harvested by man; (3) the canopy is approximately 100 feet above the ground and this allows rain droplets to reattain their terminal velocity before reaching the ground; (4) the thick canopy prevents ground cover from establishing itself; and (5) the slopes where the woodland areas are located are generally steep. It was stated by SCS that field verification of computer-projected soil loss rates in these forested areas will be made before accepting the computer results.

Harvey then briefly reviewed the sampling procedure being used in the upland study and outlined the method the SCS proposes to use for environmental assessment of the various alternatives they will investigate (i.e. habitat quality value). Harvey then turned the meeting over to George Stem.

George Stem stated that the SCS has tentatively selected Chippewa Creek and Tinkers Creek for 100 percent channel inventory. Chippewa Creek was selected because it represents an urban setting and Tinkers Creek was selected because it is the largest tributary to the Cuyahoga River. George also pointed out that the main channel inventory includes 100 percent inventory of the tributary channels up to the USGS gaging stations located at approximately the outer limit 100-year flood plain. George then passed around a draft brochure the SCS is preparing to inform the general public about the total scope of the erosion study

and stated that the SCS will not have funds to print and distribute this brochure when it is completed. George then asked if it would be possible for the Corps to print and distribute the brochure. Colonel Ludwig stated that this will be acceptable to the Corps. George also stated that the SCS is currently putting together a cassette presentation which they will use to inform local interest groups about the study.

Sharon Dougal of the East Lansing, MI, office of the U.S. Fish and Wildlife Service stated that the SCS should look very closely at the computer results and asked if the SCS will outline any problems or limitations they are having with the computer program. Harvey Kananen answered that this will be included in the SCS report. Sharon also expressed concern about expanding the sample results to the entire area. This is a valid point and was taken into consideration when the sample points were selected. The sampling points are statistically sound for each sub-watershed area and the number of sampling points was increased to approximately 13 percent to eliminate as much error as possible. Sharon stated that the Fish and Wildlife Service would like to be present when the habitat quality values are selected for the environment assessment. Harvey Kananen stated that they will be involved along with the Corps and ODNR and that the values should be selected in the near future. Sharon then asked if the SCS can relate dislodgement, as quantified by the USLE, with delivery. This is a serious problem with using the USLE that will need further investigation for this study. Sharon closed her remarks by stating that the Fish and Wildlife Service will be concerned with the effects the various alternatives for preventing erosion have on the fish and wildlife species of the area.

The SCS then presented a cassette and slide program on their Chippewa Creek flood control and bank stabilization project currently underway. The project consists of flood control structures and bank stabilization methods in the Chippewa Creek watershed to prevent flooding of a predominantly agricultural area (this Chippewa Creek is not the same creek that is tributary to the Cuyahoga River).

The meeting then adjourned for lunch at 12:00.

Afternoon Session, 15 March 1978

The SCS opened the afternoon session with a slide and speech presentation on the different types of bank stabilization construction being incorporated in the Chippewa Creek flood control project. They are using four different types of construction with emphasis being placed on preserving as many trees as possible even at increased cost. The meeting was then turned over to John Zorich who acted as moderator for the remainder of the session.

John Zorich briefly reviewed the Corps three stage planning process: (1) Plan of Study which outlines the problems and course of action to be taken in the study;, (2) PFR which addresses alternative solutions to the problems and recommends which alternatives appear most feasible for further detailed study; and (3) FFR which addresses, in detail, the recommended alternatives from the PFR and recommends one alternative for continuation into final design. John then led the discussion with the SCS in relation to this process.

The results of this discussion were that there was a misunderstanding between the SCS and the Corps about what the SCS would be required to provide in the PFR and FFR. Mr. Quilliam summarized his position by stating that the Service was under the impression that all they would provide in the FFR would be various alternatives, general in nature, with a brief environment assessment and preliminary benefit/cost ratios (B/C ratios). They thought the Corps would then do the detailed analysis on the most promising alternatives. Mr. Quilliam stated that when he originally entered into the agreement with the Corps he was trying to provide technical expertise the Corps lacked but that doing the detail engineering work, which the Corps has been involved in for many years, was not included in the agreement. Mr. Quilliam also stated that the SCS does not have the available engineering manpower to do the detailed design and analysis. John Zorich stated that the Corps was under the impression that the SCS would do the detailed engineering design and analysis required in the FFR. It may be necessary to rescope the SCS portion of the study after the SCS submits the PFR for the 3rd Interim Report on Erosion and Sedimentation. All parties agreed that another meeting between Corps and SCS should be scheduled in the near future to reach an agreement on what is required for the PFR and FFR, and who will be responsible for doing the work. (Another meeting has been scheduled for 10 a.m. on 12 April 1978 at or near Cleveland Hopkins Airport in Cleveland, OH, between the SCS and the Corps.)

The meeting was then adjourned at 3:30 p.m.

Richard E Aguglia

RICHARD AGUGLIA
Project Manager

ATTENDANCE LIST FOR
15 MARCH 1978 MEETING

Name	Organization
Daniel D. Ludwig	Corps of Engineers, Buffalo District Engineer
Robert Quilliam	Soil Conservation Service, Columbus State Conservationist
Richard Aguglia	COE, Buffalo, Planning
John Zorich	COE, Buffalo, Planning
Phil Frapwell	COE, Buffalo, Environmental
Michael Pryor	COE, Buffalo, Foundations and Materials
David Kile	SCS, Columbus
George Stem	SCS, Medina, Area Conservationist
Harvey Kananen	SCS, Medina
Don Urban	SCS, Medina
Tom Bourdon	SCS, Medina
David Click	USGS, Columbus, District Chief
Sharon Dougal	US F&WL, East Lansing, MI

Cuyahoga River Restoration Study

Summary Minutes of 16 November Interagency Coordinating Meeting

Cleveland, OH

A meeting was held on 16 November 1977 at the Executive Caterers in Cleveland, OH, to update Federal, State, Regional, and local agencies on the progress and future efforts of the study. A list of persons in attendance and the meeting agenda are attached.

Ken Hallock opened the meeting by welcoming everyone and gave a brief introduction of the project authorization. He indicated that the authorization is unusual in that it allows implementation of measures as well as investigation. The Big Creek project is one such measure which will reduce flooding in the Cleveland Zoo area.

He then introduced John Zorich. John presented a brief history of the project indicating that the original objectives of the study included flood control, recreation, aesthetics, water quality, erosion and sedimentation, harbor debris removal, Big Creek improvements, and Mantua improvements. The only items presently being studied (or to be studied) are: sedimentation and erosion, flood control in the Valley View area, and debris removal. He then outlined the present study schedule indicating that the sedimentation/erosion study will be completed at the end of FY 79 and the flood control and debris removal studies will be completed in FY 80 depending on adequate funding. John then explained the planning process used by the Corps discussing the three planning stages that each have four tasks (problem identification, formulation of alternatives, assessment, and evaluation).

Harvey Kananen of the Soil Conservation Service gave a slide presentation of the study area beginning at Old Portage and ending at Independence.

Jim Board of the U.S. Geological Survey explained the sampling program being conducted for the study. He stated that the sediment loads vary on the main river from about 40 tons per square mile at Old Portage to 290 tons per square mile at Independence. The tributaries average about 300 tons per square mile. The sampling frequency is twice per week plus high flow events on the tributaries and daily plus high flow events for the main channel. Jim stated that they have sampled about 12 or 13 high flow events. He also stated that sediment sampling will be discontinued at the Independence gage after 1 December when the present contract with the Corps expires. George Watkins expressed concern that the Independence sediment station was being discontinued and stated that some agency should provide the necessary funds for its continuation. (Subsequent action: Because the Erosion

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and Sediment Study involves the dredging of the Cuyahoga River portion of Cleveland Harbor, Buffalo District will use Operation and Maintenance funds from Cleveland Harbor to continue the sediment station at Independence through September 1978).

John Zorich stated that sediment samples have been sent to Heidelburg College for chemical analysis to be used in the Lake Erie Wastewater Management Study. This information will be available from the Buffalo District.

George Stem of the Soil Conservation Service commended the Corps for their involving other agencies in the study in order to make use of their expertise in their respective fields and he stressed the need for continued local support for the project. He gave a brief presentation of the inventory program that SCS is performing. He stated they are attempting to identify critical areas and quantify (in relative figures) the sediment produced from these areas. Harvey Kananen then gave a presentation of the information being collected in the inventory for the upland areas and the main channel. He distributed samples of the forms he is using in the inventory to the attendants and gave a brief example of how the form is used. John Zorich then stated that the preliminary report will be completed this summer and that another coordinating meeting would probably be held before the report is completed.

Bob Owens of the U.S. Fish and Wildlife Service stated that his concerns for the project are for the preservation of wildlife and habitat. He would like to work closely with the Corps and the SCS to evaluate possible impacts and would like to have F&WLS representatives participate in field inspections when alternatives are proposed.

George Watkins asked Bob if F&WL would oppose use of riprap as a means of bank stabilization. Bob replied that they are not opposed to using riprap but actually encourage its use.

The meeting then adjourned for lunch and resumed again about 1:00 p.m. John Zorich began the afternoon session stating that the purpose of this session is to allow other agencies to state their concerns and discuss their programs in the area.

Peter Smith of the U.S. Environmental Protection Agency stated that his staff is working with NOACA in their Water Quality study. His staff also reviews Environmental Impact Statements for projects in the area.

Art Waldorf of the Ohio Department of Natural Resources stated that the study had been initiated as a result of the need for flood control in the Cuyahoga Falls area. It was then decided that the total area

should be studied. He indicated that Water Quality is an important ODNR consideration along with flood control and recreation. A portion of the upper Cuyahoga has been designated as a scenic river and ODNR does not want further development in this area. Wetlands are also a concern and they have some fish and wildlife inventory information in the Cuyahoga study area. They are concerned with sediment control in the Cuyahoga and support the present Corps program.

Dave Norman of ODNR, who works with the Soil and Water Conservation Districts, is interested in the results of the study which would show the problem areas. Any type of a control program would be voluntary at this time and evidence, such as would be derived from the Cuyahoga study, is needed in order to implement a land management program.

George Watkins of the Three Rivers Watershed District explained that his organization was created by the State of Ohio to ensure that the planning in the Cuyahoga, Rocky, and Chagrin Rivers is consistent with the area's needs. The District is funded by the counties in the watershed and it has to rely on other agencies and consultants to perform its studies because of limited manpower. He stated that the priority problems in earlier years dealt with point source pollution. This problem is not as severe as before because of improvements to treatment plants in the area and of proposed improvements. Flooding has been a repetitive problem and most of the flood control studies in the area have not identified feasible projects. He was very much in favor of the Big Creek project. He then discussed the problem of land erosion and sediment being transported to the streams. In development areas, little is being done to prevent erosion since only a voluntary program now exists. Regulation and follow-up inspections are needed to effectively reduce the amount of erosion from these areas. The problem of oil spills in the river is not very serious at the present time. He is involved with an organization which has a very good system of oil recovery. The major problem with the recovery system is the separation of debris from the oil. This debris problem has increased the cost of recovery to four times greater than needed for oil recovery only. The Ohio "litter law" enforcement is necessary with a major effort directed toward educating the public of the debris problems. The Cleveland Harbor Conservation Committee is producing a movie concerning the debris problem and should be distributing it early next year. An interagency coordinating committee was formed in the early stages of the CRRS mainly to identify problems which needed to be addressed in the first Interim Report. John Zorich remarked that a coordinating committee may be useful in the remaining study effort also.

George Stem also endorsed the establishment of a coordinating committee. Ed Long, the 208 coordinator for NOACA, discussed the functions of NOACA briefly indicating that they cover five counties and a portion

of two other counties. The NOACA Board of Directors consists of 58 elected officials. The majority of their work is contracted to other agencies or private Contractors. They are presently conducting a water quality study of their area. Some of the work has been contracted to NEFCO and to the regional planning commissions. They are also gathering rainfall data and habitat information. They will analyze what the current habitat is, what it used to be, and what it could be in the future if 1983 water quality standards are met.

Dennis Bechtel of NEFCO stated they are gathering land use information and urban sediment data for NOACA in their water quality study.

Andy Vidra of NOACA explained the method they are using to determine sediment runoff. They have divided the area into 300 sub-basins and have separated urban areas from rural areas. They will then use the soil maps and use the "Universal Soil Loss Equation" to determine sediment yield assuming no protective covering for the purpose of identifying the worst potential problem areas. Then they will analyze the influence that the current land cover has on erosion and then determine the "best land management practices." John Zorich stated that this appears to be an overlap of effort but is confident that continued coordination will prevent duplication of effort. George Watkins questioned if the sampling techniques would be able to predict erosion for the entire area.

Harvey Kananen replied that the data will be expanded for the entire area. George Watkins then wanted to know if the SCS would be able to determine sediment yields independently of the USGS data. Jim Wade of the SCS explained that the program does not calculate sediment delivery into the streams. This is an estimated quantity based on judgment and the USGS data would aid in the determination. Don Urban of the SCS stated study is using a 100 percent sample of soil type and cover on a 1.2-acre cell system. The Cuyahoga study is a 20 percent sample using exact soil type, length of slope, cover, etc. The Lake Erie Wastewater Management Study is using 10-acre cells with gross soil type, cover, land use, etc. Both the LEWWMS and the 208 study are using existing data while all the information for the Cuyahoga study is being obtained in the field. George Stem stated that the program for the Cuyahoga study will identify the combination of soil type, cover, slope, etc. which presents the most potential problems and then the Ohio Capability Analysis Program system could be used to identify the location of these areas for the entire study area.

Steve Yaksich of the Buffalo District described the Lake Erie Wastewater Management Study. He stated that they are attempting to clean up Lake Erie by reducing the amount of pollutants flowing into it from the rivers. They have instituted 80 water quality stations in the Lake Erie basin. They have prepared land use maps for the basin using existing maps and NASA photos. They are using the "Universal Soil

Loss Equation" to estimate sediment yields from the watersheds and will recommend land use practices to reduce the sediment yields. They have completed a phosphorous model for the Sandusky River and are in the process of using the model on the Honey Creek watershed. They should have a report completed in the summer of 1978. John Zorich then opened the meeting for questions.

George Watkins asked what is needed for a plan to be implemented.

John Zorich replied that a plan would have to be developed that would have the benefits exceeding the costs, however, the most cost effective plan would not necessarily have to be chosen and the benefit-cost ratio could be less than 1.0 if environmental enhancement is included as an overriding factor.

George Stem stated that Bill Birdsell, who is in charge of the Cuyahoga Valley National Recreation Area, was invited to the meeting but could not attend. He will be very influential in any development plan since the majority of the study area is within the proposed park. Mr. Birdsell has a development plan along with the acquisition plan. Mr. Birdsell's prior discussions with Mr. Stem indicated that he is very much in favor of reducing the sediment carried in the Cuyahoga River.

Terry Ries of the Cleveland Metroparks System, wanted to know who would have preference in the decision-making process for the study. John Zorich replied that it would be a joint effort among all interested parties and no preference would be given to any specific organization.

Ken Hallock thanked everyone for their participation and cooperation during the meeting and stated that another meeting would be held sometime in the summer of 1978.

The meeting adjourned at approximately 3:30 p.m.

Ralph Henry
RALPH HENRY
Project Manager

ATTENDANCE LIST FOR
16 NOVEMBER 1977 MEETING

NAME	ORGANIZATION
Andrew Vidra	NOACA
E. B. Long	NOACA
Nathaniel Wilder	NOACA
Dennis Bechtel	NEFCO
Jacquie Kennedy	Summit County Planning Department
Don Zazo	Summit County Sanitary Engineer
Sharon Yerkey	Cuyahoga County Regional Planning Commission
Jim Kastelio	Cuyahoga County Regional Planning Commission
James Kananen	Portage County Regional Planning Commission
Terry A. Ries	Cleveland Metroparks System
George Watkins	Three Rivers Watershed District
Art Waldorf	ODNR
David A. Norman	ODNR
David Baker	Heidelberg College
Peter E. Smith	USEPA
Robert Owens	USF&WL
David E. Click	USGS
James Board	USGS
Jesse Klingler	USGS
George Stem	SCS
Don Urban	SCS
Jim Wade	SCS
Harvey Kananen	SCS
Jim Steiner	SCS
Dave Samples	SCS
Thomas Anderson	SCS
Adrian Achtermann	SCS
John Gerlach	SCS
John Hocker	SCS
Fred Kramer	Cuyahoga County Soil & Water Conservation District
Jay Goodell	Portage County Soil & Water Conservation District
Larry Peters	Portage County Soil & Water Conservation District
Kenneth Hallock	Corps of Engineers
John Zorich	Corps of Engineers
Steve Yaksich	Corps of Engineers
Ralph Henry	Corps of Engineers

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AGENDA
for
Interagency Technical Input and Information Meeting
on
Erosion and Sedimentation Feasibility Study (3rd Interim Report)
Cuyahoga River Restoration Study
Wednesday, 16 November 1977
Executive Caterers, Inc., 27629 Chagrin Boulevard
(at State Routes 87 & 422 at I 271), Cleveland, Ohio

10:00 a.m.	Welcome and Opening Remarks	Kenneth Hallock, Acting Chief, Engineering Division Corps of Engineers
10:10 a.m.	History of Cuyahoga River Restoration Study and Future Study Objectives	John Zorich, Chief, Western Basin Ralph Henry, Project Manager Corps of Engineers
10:40 a.m.	Orientation by Slides	Harvey Kananen Soil Conservation Service
11:00 a.m.	Responsibilities and Activities a. Stream Gage Monitoring	James Board Jesse Klingler United States Geological Survey
11:20 a.m.	Responsibilities and Activities	George Stem Soil Conservation Service
	a. Upland Erosion and Sedimentation Inventory	Harvey Kananen, SCS
	b. Channel Inventories	
11:40 a.m.	Comments by U. S. Fish and Wildlife Service, East Lansing, MI	Sharon Dougal Natural Resource Ecologist
11:50 a.m.	Lunch	
1:00 p.m.	Afternoon Session - Open Discussion and Reports on Interrelated Programs by other Interested Agencies. Moderator	Ralph Henry, C of E
3:00 p.m.	Closing Remarks	Kenneth Hallock, C of E

Attachment 2

APPENDIX G

PERTINENT CORRESPONDENCE

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

APPENDIX G
PERTINENT CORRESPONDENCE

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The Cleveland-Cliffs Iron Company

Offices 14th Floor Union Commerce Building

Cleveland, Ohio 44115

July 23, 1979

Colonel George P. Johnson
District Engineer
U. S. Army Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Johnson:

Enclosed is a set of photographs taken on July 9, 1979 by Captain David Lindmark of our S/S CHAMPLAIN showing debris floating in the Cuyahoga River following a rainstorm.

The Cuyahoga River has a history of loading up with floating debris, oil, and a considerable amount of silt which drops at the bottom in the vicinity of the Upper Republic Dock and at certain turns in the river. I suggest that the Corps of Engineers continue to investigate the possibility of restricting devices above navigation to catch the flow of debris and silt which interfers with navigation in the Cuyahoga project.

Sincerely,

John L. Horton

John L. Horton
Manager, Marine Division

JLH:cal
Enclosure

cc: Captain David Lindmark

EXHIBIT G-1

S/S CHAMPLAIN - JYAHOGA RIVER DEBRIS - JULY 9, ,9

PICTURFS TAKEN BY CAPTAIN DAVID LINDMARK

Republicsteel

Republic Steel Corporation
General Offices: Republic Building
Traffic Shipping and
Transportation Department
PO Box 6778
Cleveland OH 44101

Hugh Tobin
EM Fowell
PR Wysor
WH Cramer
ZA McGinnis
FW Thomas
SR Waldron

February 20, 1979

In reply refer to file
number 100-H-3

Colonel Daniel D. Ludwig
U. S. Army Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Col. Ludwig:

The Great Lakes Steamship Companies that serve the Republic Steel Docks on the Cuyahoga River in Cleveland, Ohio have, for many years, complained about the severe shoaling that often occurs in the river near or alongside our docks.

This sedimentation that results from runoff from land adjacent to the river, city streets, sewers, etc. accumulates faster than normal dredging can remove it. Heavy spring and summer rains aggravate the problem.

Hopefully, another method of reducing the flow of this sediment into the river or a control of sedimentation above the navigation limits of the Cuyahoga River is possible.

We would appreciate it if the U. S. Army Corps of Engineers would consider other methods of sedimentation control as well as dredging to maintain the Cuyahoga River at project depth.

Very truly yours,

Z. A. McGinnis
Asst. Traffic Manager

ZAM:jn

cc: A. A. Apotsos

EXHIBIT G-

The Cleveland-Cliffs Iron Company

Offices 14th Floor Union Commerce Building

Cleveland, Ohio 44115

February 13, 1979

Colonel Daniel D. Ludwig
U. S. Army Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel:

Sedimentation control into the Cuyahoga River from farmlands, city streets, sewers, and general deteriorated bank areas is most important to prevent serious shoaling of the upper reaches. Soil accumulations at various turns in the river will also be reduced if soil runoff can be controlled. The same sediment is also most visible in the open lake following a summer rain runoff into the river.

The soil should be retained at its original sources or an endeavor should be made to restrain the sediment from flowing into the navigable portions of the river by control above the navigation limits. The following points should be considered:

1) Winter and spring sedimentation reduces river draft faster than the Corps is economically able to maintain the authorized depths. It is not unusual for a heavy rainstorm to produce channel depth reduction as much as 1' in the upper reach of the river.

2) Each spring the river is reduced to a 12' to 17' depth in the upper reaches of the river. Vessels transiting to the Upper Republic Dock are required to lighter in order to make passage and get close enough to the dock to unload.

3) Dredging operations each spring are not mustered early enough to remove this winter-spring runoff and consequent sedimentation drop until as late as May 1 and on many occasions June 1. The 1978 dredging program never cleaned out the sedimentation.

4) The passage of a vessel through 2' or 3' of the soft sediment is most difficult for the vessel Master in that the ship will occasionally take an unplanned turn from the river channel and in many cases may contact bridge abutments or other ships.

5) Sedimentation will plug vessel intakes causing main engines to loose vacuum and cease operating. The power plant shutting down may require as long as 1 to 4 hours to reactivate.

EXHIBIT G-3

6) Sedimentation enters the ship ballast system as the vessel takes on about 5,000 tons of ballast water for purposes of handling the ship when departing the harbor. It is estimated that about 50 tons of sedimentation is accumulated in the ballast tanks each year. This sediment accumulates to about 150 to 200 tons before the ship is opened and the sediment is physically removed at about a cost of from $50,000 to $100,000 depending upon the availability of labor and labor charges. A system called Zimmite is used through the season in an endeavor to loosen the sediment from the ballast tanks so that it will pump out at a cost of $3,500 per ship. Approximately 500 cargoes are delivered into the Cuyahoga River each year and each of these ships has a potential cargo reduction of the sediment carried in the ballast tanks.

Vessels are lightered at outside docks on some occasions and then proceed up the river at a reduced draft. This incurs transfer of cargo by railroad to the final destination and adds an increase charge to the cost of the delivery of the cargo.

7) The vessels destined to the Upper Republic Dock practically all require lightering at the lower dock during the months of April and May in order to service and deliver needed iron ore to the blast furnace at the upper location. This means a loss of time while waiting for the lower dock on some occasions and for the lightering service to be accomplished before proceeding to the Upper Republic Dock.

8) The recent high water has made the sedimentation effects less severe. Normal water levels will reduce vessel draft and will reduce cargoes carried.

Sincerely,

John Horton

John L. Horton
Manager
Marine Division

JLH:cal

REPORT TO THE CHIEF

Woodland Erosion
Cuyahoga River Basin
Summit County, Ohio

On July 26 and 27, 1978, myself and representatives of the U.S. Forest Service, National Park Service (NPS) and the Soil Conservation Service met to examine woodland in the Cuyahoga River drainage for excessive erosion. The following persons were in attendance: Frank Toth, Division of Forestry; Bernard Dickerson, U.S. Forest Service; Rod Royce and Terry Miller, National Park Service; David Berna, Glen Bernath, George Stem, Harvey Kananen, Donald Urban, Donald Pettit, Soil Conservation Service.

Three Permanent Sampling Units (PSU), 90-100 acres in size, were inspected in the Furnace Run tributary of the Cuyahoga River Basin. The PSU's checked were No's. 402, 403 and 111. See enclosed map of portion of the Peninsula, Ohio, Quadrangle. The Universal Soil Loss equation was used to compute erosion.

PSU #402

GENERAL

This PSU is located on private land in Richfield Township, Summit County, Ohio. Soils are mostly Glacial Till, of the highly erodable Ellsworth Soil Series. This is primarily a north facing slope under woodland cover. Percent of slope is around 10-20%. Red Oak, Ash, Magnolia, Maple, Hickory and Yellow Poplar are the dominant tree species.

WOODLAND DESCRIPTION

The Red Oak-Hickory Timber type predominates in the stand in association with Ash, Magnolia, Maple, Hickory, Yellow Poplar and other assorted species. Stocking varies from 30-120 BA. The trees, in general, are fairly tall, with estimated site index of medium to high. The area was cut over quite heavily in World War II, taking out nearly all of the sawtimber. As a result there is now a nice second growth stand of around 35 years of age. Understory reproduction is fair, but not what it should be. There has been some light grazing in the stand, but not severe. This may account for the lack of reproduction.

Some of the trees in the stand have been marked for harvest. However, I believe that it was marked by a log buyer and not a Service Forester. We also noticed marking in the other PSU's as well.

WOODLAND EROSION

Considerable bare ground was showing. There seems to be little accumulation of litter cover, with resultant erosion. Wherever good litter cover was in eveidence there was little erosion.

Many trees were standing on their roots, 5" or 6" above the soil surface, indicating considerable sheet erosion. There was also some rill and gully erosion in evidence. One gully was traced back to its source on an openflat at the top of the hill. There is presently some oil drilling activity at this point. I believe that some of the erosion can be put at the oil drilling site. However, this doesn't explain all the erosion, even though I think that it is a contributing factor.

According to some research conducted by Michigan Technological University on raindrop erosion, it has been reported that a forest canopy does not shelter the soil from raindrop splash erosion. "Several investigations have observed that the Kinetic Energy of rain is amplified by the forest canopy. It has been shown that overstory and understory canopies will not normally act to shelter or shield the forest floor from the erosive imparts of raindrops. Although it is evident that much more information is needed on drop size distribution and raindrop behavior beneath forest canopies, these preliminary results indicate that erosion processes in forested areas should be centered on the properties and dynamics of the litter layer and the organic fraction in the surface horizon of forest soils."*

Whether raindrop erosion is a dominant factor in this particular area is not known, but it could certainly be contributory. In all of my experience this is the first time that I have observed this erosion phenomena under forest cover. This type of erosion is virtually unknown under conifers, probably because of the heavy duff layer of needles and litter. Where there is ample litter cover there is little erosion.

The landowner is planning to build a golf course in this particular area at some future date. This may be a solution to the problem, by clearing it, and putting it under grass cover.

Another solution would be to clearcut this area and let it regenerate back to natural hardwood cover, assuming erosion wouldn't be accelerated. The area could also be planted to conifers to help build up the litter layer.

PSU #403

GENERAL

This PSU is also located in Richfield Township, Summit County and is on National Park Service land of the Cuyahoga Valley National Recreation Area. The PSU is bisected by Furnace Run. This area was covered quite thoroughly by the inspection team.

Again this an Ellsworth Soil series leaning to more clay than sand on the south side, and sandier on the north. The terrain is considerably steeper than in PSU #402.

*Dohrenwend, Robert E. Raindrop Erosion in the forest, Research Notes No. 24, September 1977, Michigan Technological University, Ford Forestry Center, Lance, Michigan, 49946. Pages 1, 16 and 17.

WOODLAND DESCRIPTION

The southside of the PSU faces to the northeast, so is a fairly good timber growing site. More oak is in evidence with somewhat better reproduction than PSU #402. Timber type is primarily white oak with hickory, yellow poplar, sugar maple, sycamore and blue beech. The stand is roughly ½ sawtimber and ½ poletimber. Basal Area on the average seemed to be higher, overall, than in PSU #402, running about 120 BA. The sawtimber in the stand is pretty good size, with no decline in growth rate in evidence this is a good timber growing site and I would estimate site Index as high to very high.

The flood plain of the creek is comprised primarily of the Elm-Ash-Sycamore Timber Type of about average size and growth. Some evidence of flooding was noticed.

The north side of the PSU faces southwest. The dominant timber is again White Oak, in association with sugar maple and yellow poplar. This is another good growing site.

WOODLAND EROSION

South side

Some soil slippage was in evidence in this area, also some gullying. However, due to the more abundant reproduction and accompanying leaf litter, erosion was not near the problem as in PSU #402, even though the slopes were, on the average, longer and steeper. Because of the longer and steeper slopes, the Universal Soil Loss Equation (USLE) showed this area as having a high degree of erosion. However, from my observations the erosion did not seem to be very serious. This makes me question the validity of the USLE to forest land. I think more research needs to be done in this area.

Floodplain of Furnace Run

Erosion was rather severe in this portion of the PSU. Considerable scouring was noted in the floodplain, probably due to high water of the creek at flood stage. The creek bank showed considerable erosion, with some sloughing of the bank. Some vegetation was trying to stabilize those banks, but without much success. Much of the soil along the bank was sterile, washed clear to clay hardpan, with the topsoil eroded away. I would say that the bank sloughing is contributing considerably to the sediment load of Furnace Run, and to the Cuyahoga River.

North side

The soils in this portion of PSU #403 were more sandy than the southern and central parts. The slopes were quite steep and long, leveling out into a bench and then dropping to the flood plain. Little erosion was noticed, as the litter cover was quite good. Again the USLE indicated this area as a high erosion hazard, but it didn't show it.

AD-A103 919 CORPS OF ENGINEERS BUFFALO NY BUFFALO DISTRICT F/G 8/8

CUYAHOGA RIVER, OHIO RESTORATION STUDY. THIRD INTERIM PRELIMINA--ETC(U)

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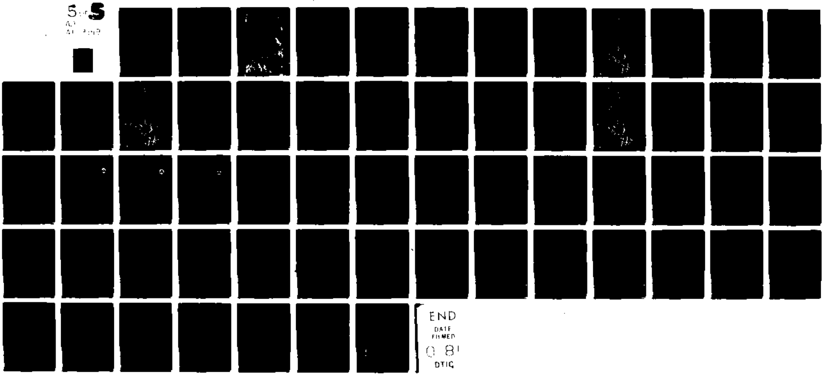

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DTIC

The most erodable part was wheatley Run, which is tributary to Furnace Run. Many trees had sloughed off the bank and into the creek causing some damming of the tributary. Some sediment had collected behind the down trees. This may be adding to the sediment load of Furnace Run.

It appears to me that most of the erosion in this portion is natural geologic erosion and not particularly out of the ordinary. I think more study needs be done in this portion of the PSU, particularly in the Wheatley Run tributary.

PSU #111

General

Most of this area is located on NPS land in Boston Township, Summit County. The bulk of this PSU is on a southeast facing slope. Part of the private portion of this area is being farmed.

Woodland Description

Stand composition of this area includes Oak, Sugar Maple and Yellow Poplar. Part of this property was harvested prior to purchase by the NPS. A portion of this area was clearcut resulting in heavy reproduction of the desirable shade intolerant species. A young, vigorous stand of seed-saps presently occupies the cut over area.

Woodland Erosion

Little or no erosion was observed in this PSU. The clearcut has regenerated back to heavy ground cover of young reproduction, and the undisturbed areas show no erosion to speak of.

CONCLUSIONS

From this study, I would conclude that there is an erosion problem in PSU #402, and something definately needs to be done. In PSU #403 the major problem is along Furnace Run and also in the Wheatley Run tributary. Little erosion was noted in PSU #111.

The Universal Soil Loss Equation (USLE) shows considerable erosion coming from the aforementioned areas. In PSU #402 I am in agreement with the USLE, however, in the other areas where slopes are steeper and longer I question the applicability of the equation to these forest lands. I think more needs to be done in relating the USLE to forest land. I concur with Mr. Floyd Wiles letter of 7/3/78/ to George Stem recommending the following:

1. Initiate a mainstream channel study on Furnace Run.

2. Conduct an in-depth stream bank erosion study on a tributary of Furnace Run; preferably Wheatley Run.

3. Simultaneously conduct a preliminary appraisal of sediment yields from the gullies within the Wheatley Run area.

4. Re-evaluate the impact of sheet erosion from forest lands relative to the above findings.

I think that more needs to be done in this area before final conclusions are drawn.

Respectfully submitted,

Franklin K. Toth

Franklin K. Toth
Assistant Staff Forester


BALTIMORE

Stabilization and stream improvement must be compatible with fish and wildlife and recreation uses. Stabilization will be more aesthetically pleasing if it is natural in aspect and blends with the surroundings. Timber cribs and riprap placed, without mortar, against the eroding bank, as shown in Figures C-4 and C-5, combined with riparian vegetation, such as birches, planted above the ice line on the bank, can be both functional, attractive, and not unduly expensive.

Remedial Actions

Settling Basin:

Of the 1,250,000 cubic yards of sediment reaching the Cleveland Harbor annually, an estimated 550,000 cubic yards; a volume approximating that dredged from the upper portion of the navigation channel; can be collected by an upstream settling basin and removed to suitable disposal areas.

The recommended location of the settling basin, shown on Plate C-3 as site 8, lies between river miles 8 and 9, approximately two miles upstream from the head of navigation. The recommended area, approximately 5,000 feet in length and 1,000 feet wide, is presently undeveloped. The shape of the settling basin depends on the type of facility used.

Suitable sites for the disposal of the spoil include two landfill areas, identified as sites 3 and 4 on Plate C-3, near the proposed settling basin, as well as various proposed diked disposal areas in the Cleveland Outer Harbor. Site 3 is located about ten miles above the mouth of the Cuyahoga River. The site is presently a gravel pit, experiencing limited use, and would hold the volume of sediment that could be collected in the settling basin in about five years, i.e., 2,750,000 cubic yards, without providing dikes or other closure structures. This disposal area is accessible from the proposed settling basin via a one-mile haul road, that does not interfer with city traffic. Site 4, located approximately 1,000 feet beyond site 3 from the settling basin, is undeveloped except for power lines passing through the area. It, too, would hold about five years of spoil from the settling basin without requiring dikes or other closure structures. Road access to site 4 would require extension of the haul road across a Cleveland thoroughfare.

There are several possible operating plans for removal and disposal of the sediment. Three considered were a Sauerman lift bucket with truck removal, hydraulic removal, and a combination of hydraulic removal with ship removal of the sediment. These three alternatives are discussed below.

Inclosure 1

The first alternative includes a Sauerman tower cable excavating system which could remove the sediment directly from the basin and dump it into trucks for transportation to the landfill sites. The Sauerman facility would necessitate a rectangular basin configuration approximately 4,000 feet long, with a bottom width of 300 feet. The side slopes would be 1 vertical on 2.5 horizontal, and at normal river levels the depth would be approximately 22 feet. The material obtained from the original basin excavation would be used for a fill parallel to the basin on the right bank, thus reducing the height of the Sauerman tower installed and bringing the trucks within a more efficient distance from the loading bucket. Details of the Sauerman facility are shown on Plate C-4, and the costs are shown in Table C-1.

TABLE C-1 Costs for Sauerman Dredging System

First Cost	
Settlement basin: Site #8	
Lands	$ 900,000
Excavation and dikes	2,427,000
Sauerman system	1,106,000
Disposal site #3	
Lands	240,000
Construction	75,000
Disposal site #4	
Lands	300,000
Construction	225,000
Subtotal	$5,273,000
Engineering and Design	192,000
Supervision and Administration	228,000
Total	$5,693,000
Salvage Value	-250,000
First Cost Less Salvage	$5,443,000
Average Annual Cost	
Interest, $5,443,000 @ 5-3/8% =	$ 293,000
Amortization, 10 year life @ 5-3/8% =	425,000
Truck haul, 550,000 c.y. @ $0.38 =	209,000
Dredging, operation and maintenance 550,000 c.y. @ $0.20 =	110,000
Total	$1,037,000

Average cost per cubic yard removed = $1.89

Although the Sauerman dredging facility would preclude rehandling the sediment, the nature of the settled material could seriously reduce the effectiveness of the Sauerman. Composite sediment samples, taken at Independence, demonstrate a grain size distribution consisting of 87 per cent silt or clay. The loss of these fine particles during

the sediment removal effectiveness. During the project life, park facilities may be constructed along the basin banks, with the ultimate conversion of the basin area to a complete recreational facility.

The third alternative provides for the hydraulic pumping of the spoil from the settling basin to the head of navigation, where it would be transferred to a waterborne vessel and transported to one of several proposed diked disposal areas in the Cleveland Outer Harbor. Final selection of the harbor disposal site will depend on minimization of adverse environmental impacts. The various possible diked disposal areas are shown in Figure C-6. The difficulties of pumping the material, and the cost and operation of the large vessels required, make this alternative undesirable.

The cost of the current method of dredging sediment and disposing of it in diked disposal areas, based on bid proposals of August 1971, is $4.66 per cubic yard dredged and placed in the present diked disposal area. This compares with $1.89 per cubic yard dredged and placed in disposal sites under the Sauerman method and $1.75 per cubic yard with the hydraulic method.

The settling basin and nearby disposal sites at the proposed location present the potential for various experimental water quality enhancement measures. For example, injection of polyelectrolytes immediately upstream of such basins has been shown to increase the effectiveness of sediment removal. Incidental to this sediment removal, significant reduction in organic materials and bacteria has been demonstrated.

Another potential demonstration technique involves chemical coagulation and precipitation of phosphates, followed by dredging of the precipitate with the sediment. The recommended location of the settling basin immediately downstream of the Cleveland Southerly Wastewater Treatment Plant, where the maximum concentration of phosphates in the stream occurs, is ideal for such an investigation.

Finally, in-stream aeration of the river water leaving the basin, after successful removal of organic material, can be expected to improve the quality of the river water in the stretch between the settling basin and the head of navigation, improving the self-cleaning capability of the river, and ultimately reducing the contamination of Lake Erie.

Before any projects are undertaken, measurements and analyses must be made to determine baseline conditions. Additional measurements would be made during and after any project to evaluate its effects.

the lift of 22 feet through the overlying water is expected to be significant, resulting in the possible transportation of large volumes of water with the spoil.

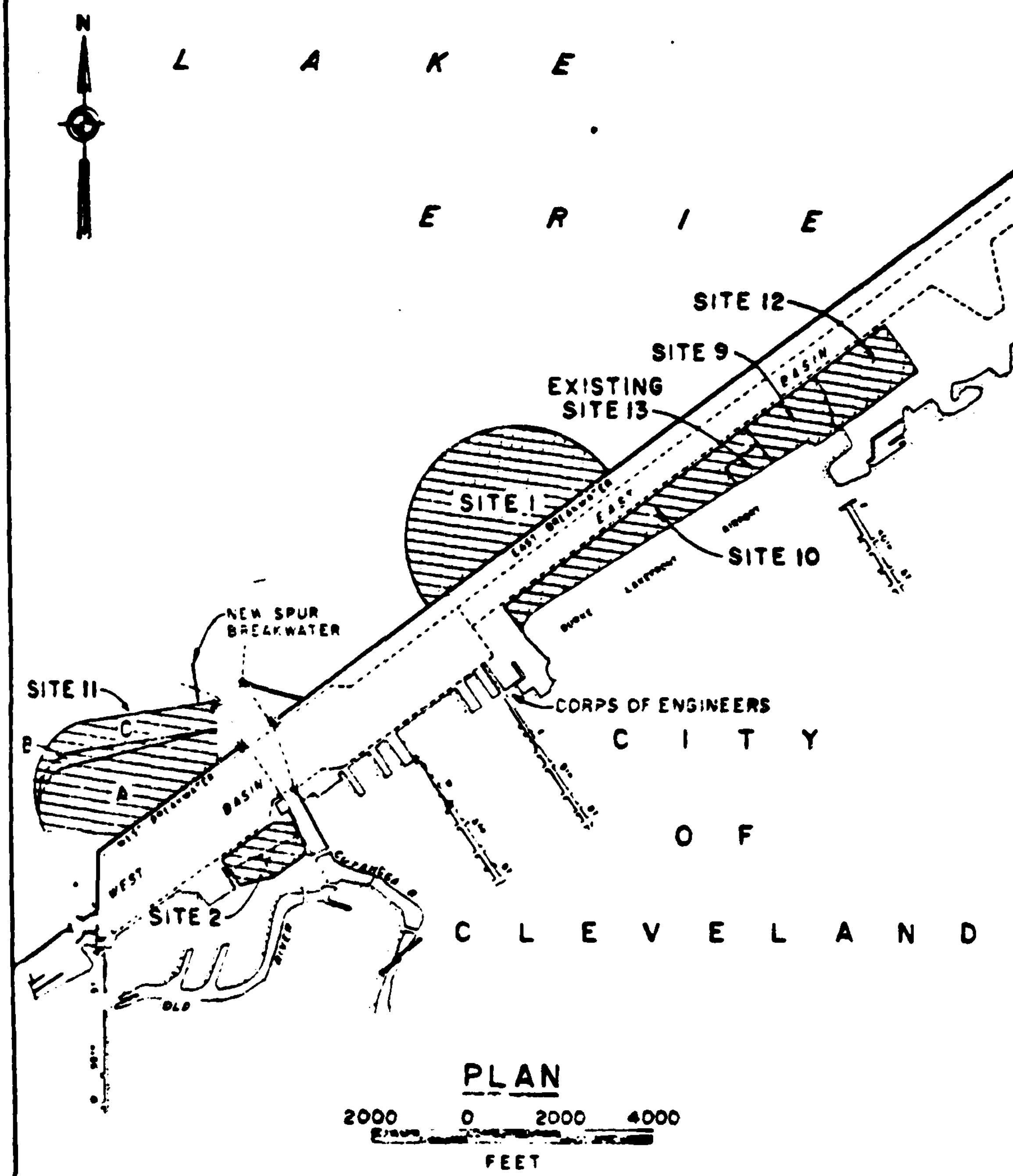
A second alternative includes hydraulic removal and transportation of the spoil to disposal sites 3 and 4. The transmission pipes associated with this plan would require easements similar to those for haul roads, with the advantage of burying the pipes beneath the street separating the two disposal areas. This alternative also precludes rehandling the spoil. The costs of this alternative are shown in Table C-2.

TABLE C-2 Costs for Hydraulic Dredging System

	First Cost	
Settlement basin: Site #8		
Lands		$ 800,000
Excavation		1,440,000
Hydraulic system		790,000
Disposal sites #3 and #4		
Lands		540,000
Construction		249,000
Subtotal		$3,819,000
Engineering and Design		148,000
Supervision and Administration		173,000
Total		$4,140,000
	Average Annual Cost	
Interest, $4,104,000 @ 5-3/8%	=	$ 223,000
Amortization, 10 year life @ 5-3/8%	=	323,000
Dredging, operation and maintenance for 550,000 c.y. @ $0.76	=	419,000
Total		$ 965,000

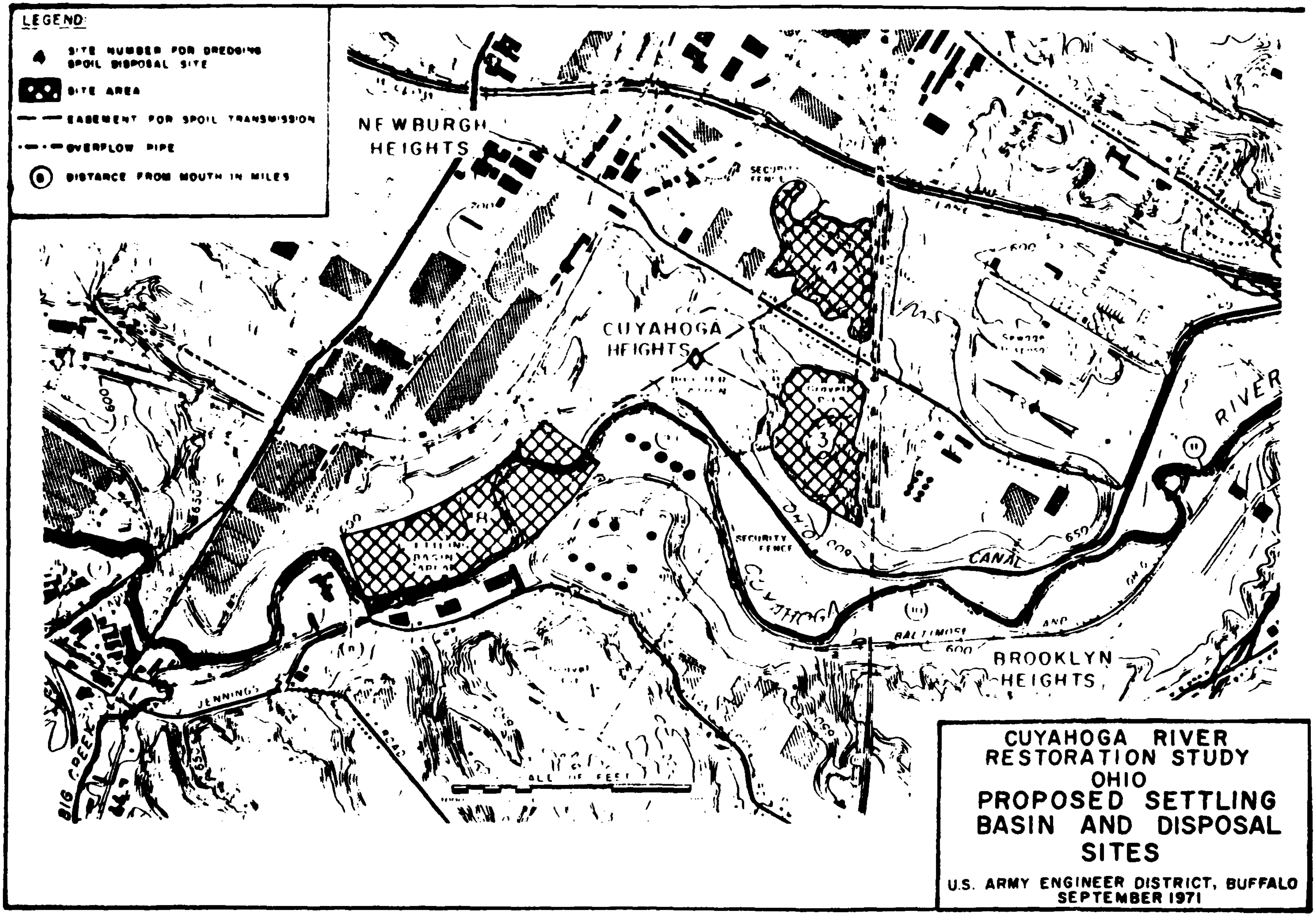
Average cost per cubic yard removed = $1.75

The hydraulic dredging alternative becomes increasingly attractive in light of the overall objectives of the river restoration study. The hydraulic dredging equipment requires no particular basin configuration, nor rails and towers, thus precluding the industrial appearance associated with the Sauerman facility. The settling basin design can include both sediment removal and recreation. The configuration of the basin can approach that of a natural lake, improving the landscape, while not significantly decreasing



HARBOR DISPOSAL SITES

FIGURE C-6



CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN AND DISPOSAL SITES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
SEPTEMBER 1971

PLATE C-3

Stabilization and stream improvement must be compatible with fish and wildlife and recreation uses. Stabilization will be more aesthetically pleasing if it is natural in aspect and blends with the surroundings. Timber cribs and riprap placed, without mortar, against the eroding bank, as shown in Figures C-4 and C-5, combined with riparian vegetation, such as birches, planted above the ice line on the bank, can be both functional, attractive, and not unduly expensive.

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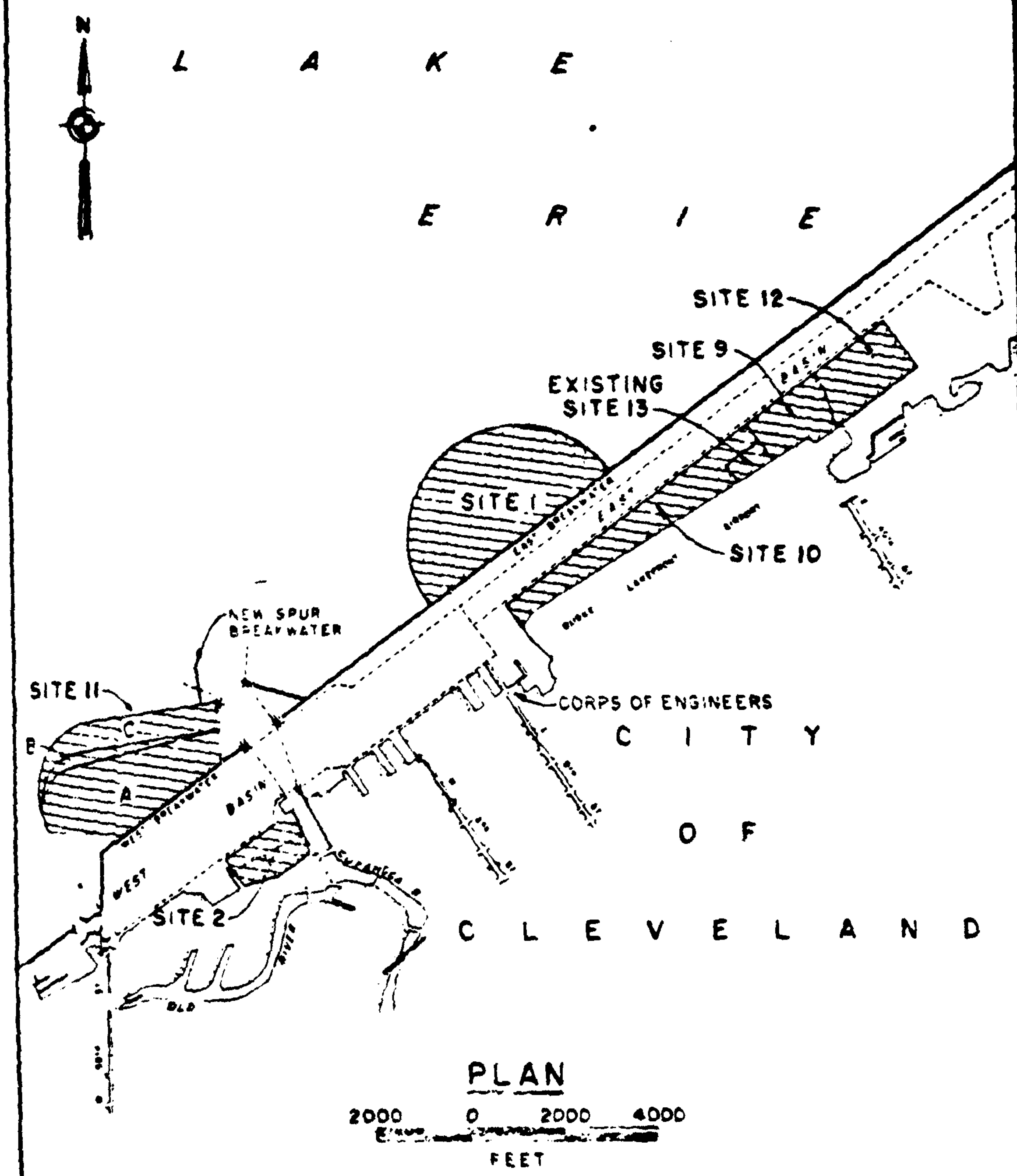
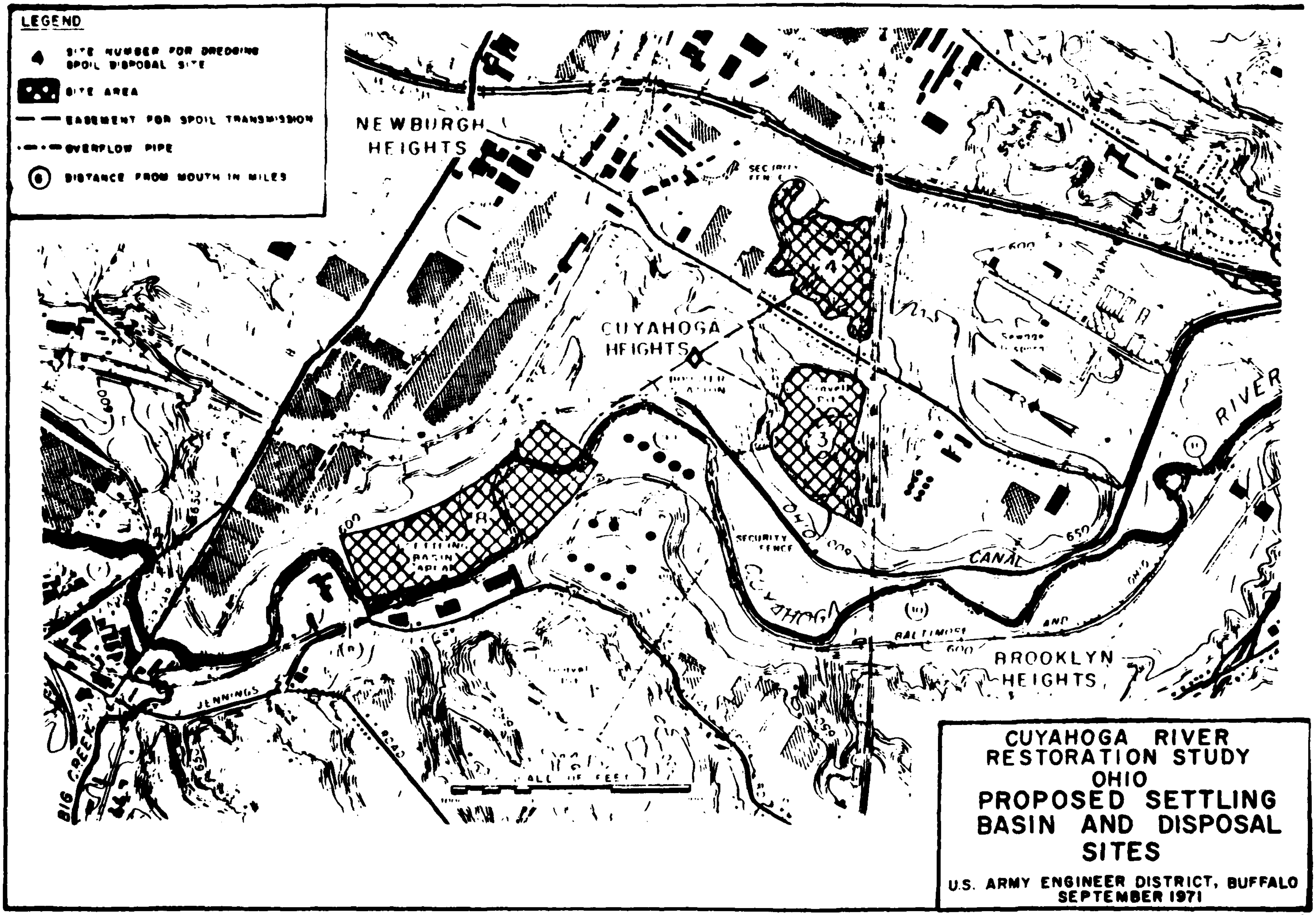


HARBOR DISPOSAL SITES

FIGURE C-6



CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN AND DISPOSAL SITES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
SEPTEMBER 1971

PLATE C-3

NCBED-PW 5 April 1979

George Watkins, Secretary-Treasurer
Three Rivers Watershed District
1204 Superior Building
Cleveland, OH 44114

Dear Mr. Watkins:

In September 1971, the Buffalo District completed the First Interim Report for the Cuyahoga River Restoration Study. As part of this report, the Buffalo District Engineer recommended that four early-action programs be adopted. During its review of this report, the Board of Engineers for Rivers and Harbors (BERH) concluded, among other things, that a settling basin on the Cuyahoga River should also be considered as an early-action program. Accordingly, the Board conducted a public meeting on 19 January 1972, at Cleveland, Ohio, on the considered modifications. Based on the information presented at this meeting, the Board concluded that local interests were not prepared at that time to provide the required items of local cooperation for the settling basin and noted that substantial environmental issues would have to be resolved before implementing the plan. The Board, therefore, recommended that a settling basin on the Cuyahoga River be given further study and be considered for construction if the environmental issues could be resolved and the items of local cooperation met.

The Buffalo District is currently preparing, in conjunction with the U.S. Soil Conservation Service, a Preliminary Feasibility Report (PFR) on Erosion and Sedimentation in the Cuyahoga River Basin between Independence (river mile 13.8) and Portage Path (river mile 40.5) for the Cuyahoga River Restoration Study. The objectives of this PFR are to determine the prolific sources of sediment throughout the study area (from land and streambank erosion) and to identify methods of controlling erosion and sedimentation through structural and/or nonstructural means. We will provide you a copy of this report when it is completed.

EXHIBIT G-7

NCBED-PW
George Watkins, Secretary-Treasurer

As an alternative to controlling erosion and sedimentation in the study area, the Buffalo District proposes to reexamine the settling basin concept outlined in the First Interim Report and considered by the Board for an early-action program. For your convenience, the pertinent information presented in the First Interim Report on the settling basin concept is provided in Inclosure 1.

At the 10 January 1972 public meeting, your agency expressed its reservations about the feasibility of the settling basin concept. A copy of your agency's statement, presented at this public meeting, is provided in Inclosure 2. It is requested that you review your agency's previous position on this matter in light of current conditions and provide me with your current views in order that we may incorporate them into our formulation and assessment of this alternative. A timely response to this request will be appreciated.

If you have questions on this matter, please contact me or Mr. Richard Aguglia, my project manager for the Cuyahoga River Restoration Study, at (716) 876-5454, extension 2263.

Sincerely yours,

2 Incl
as stated

DANIEL D. LUDWIG
Colonel, Corps of Engineers
District Engineer

Stabilization and stream improvement must be compatible with fish and wildlife and recreation uses. Stabilization will be more aesthetically pleasing if it is natural in aspect and blends with the surroundings. Timber cribs and riprap placed, without mortar, against the eroding bank, as shown in Figures C-4 and C-5, combined with riparian vegetation, such as birches, planted above the ice line on the bank, can be both functional, attractive, and not unduly expensive.

Remedial Actions

Settling Basin:

Of the 1,250,000 cubic yards of sediment reaching the Cleveland Harbor annually, an estimated 550,000 cubic yards; a volume approximating that dredged from the upper portion of the navigation channel; can be collected by an upstream settling basin and removed to suitable disposal areas.

The recommended location of the settling basin, shown on Plate C-3 as site 8, lies between river miles 8 and 9, approximately two miles upstream from the head of navigation. The recommended area, approximately 5,000 feet in length and 1,000 feet wide, is presently undeveloped. The shape of the settling basin depends on the type of facility used.

Suitable sites for the disposal of the spoil include two landfill areas, identified as sites 3 and 4 on Plate C-3, near the proposed settling basin, as well as various proposed diked disposal areas in the Cleveland Outer Harbor. Site 3 is located about ten miles above the mouth of the Cuyahoga River. The site is presently a gravel pit, experiencing limited use, and would hold the volume of sediment that could be collected in the settling basin in about five years, i.e., 2,750,000 cubic yards, without providing dikes or other closure structures. This disposal area is accessible from the proposed settling basin via a one-mile haul road, that does not interfer with city traffic. Site 4, located approximately 1,000 feet beyond site 3 from the settling basin, is undeveloped except for power lines passing through the area. It, too, would hold about five years of spoil from the settling basin without requiring dikes or other closure structures. Road access to site 4 would require extension of the haul road across a Cleveland thoroughfare.

There are several possible operating plans for removal and disposal of the sediment. Three considered were a Sauerman lift bucket with truck removal, hydraulic removal, and a combination of hydraulic removal with ship removal of the sediment. These three alternatives are discussed below.

Inclosure 1

The first alternative includes a Sauerman tower cable excavating system which could remove the sediment directly from the basin and dump it into trucks for transportation to the landfill sites. The Sauerman facility would necessitate a rectangular basin configuration approximately 4,000 feet long, with a bottom width of 300 feet. The side slopes would be 1 vertical on 2.5 horizontal, and at normal river levels the depth would be approximately 22 feet. The material obtained from the original basin excavation would be used for a fill parallel to the basin on the right bank, thus reducing the height of the Sauerman tower installed and bringing the trucks within a more efficient distance from the loading bucket. Details of the Sauerman facility are shown on Plate C-4, and the costs are shown in Table C-1.

TABLE C-1 Costs for Sauerman Dredging System

First Cost	
Settlement basin: Site #8	
Lands	$ 900,000
Excavation and dikes	2,427,000
Sauerman system	1,106,000
Disposal site #3	
Lands	240,000
Construction	75,000
Disposal site #4	
Lands	300,000
Construction	225,000
Subtotal	$5,273,000
Engineering and Design	192,000
Supervision and Administration	228,000
Total	$5,693,000
Salvage Value	-250,000
First Cost Less Salvage	$5,443,000
Average Annual Cost	
Interest, $5,443,000 @ 5-3/8% =	$ 293,000
Amortization, 10 year life @ 5-3/8% =	425,000
Truck haul, 550,000 c.y. @ $0.38 =	209,000
Dredging, operation and maintenance 550,000 c.y. @ $0.20 =	110,000
Total	$1,037,000

Average cost per cubic yard removed = $1.89

Although the Sauerman dredging facility would preclude rehandling the sediment, the nature of the settled material could seriously reduce the effectiveness of the Sauerman. Composite sediment samples, taken at Independence, demonstrate a grain size distribution consisting of 87 per cent silt or clay. The loss of these fine particles during

the lift of 22 feet through the overlying water is expected to be significant, resulting in the possible transportation of large volumes of water with the spoil.

A second alternative includes hydraulic removal and transportation of the spoil to disposal sites 3 and 4. The transmission pipes associated with this plan would require easements similar to those for haul roads, with the advantage of burying the pipes beneath the street separating the two disposal areas. This alternative also precludes rehandling the spoil. The costs of this alternative are shown in Table C-2.

TABLE C-2 Costs for Hydraulic Dredging System

	First Cost	
Settlement basin: Site #8		
Lands		$ 800,000
Excavation		1,440,000
Hydraulic system		790,000
Disposal sites #3 and #4		
Lands		540,000
Construction		249,000
Subtotal		$3,819,000
Engineering and Design		148,000
Supervision and Administration		173,000
Total		$4,140,000
	Average Annual Cost	
Interest, $4,104,000 @ 5-3/8%	=	$ 223,000
Amortization, 10 year life @ 5-3/8%	=	323,000
Dredging, operation and maintenance for 550,000 c.y. @ $0.76	=	419,000
Total		$ 965,000

Average cost per cubic yard removed = $1.75

The hydraulic dredging alternative becomes increasingly attractive in light of the overall objectives of the river restoration study. The hydraulic dredging equipment requires no particular basin configuration, nor rails and towers, thus precluding the industrial appearance associated with the Sauerman facility. The settling basin design can include both sediment removal and recreation. The configuration of the basin can approach that of a natural lake, improving the landscape, while not significantly decreasing

the sediment removal effectiveness. During the project life, park facilities may be constructed along the basin banks, with the ultimate conversion of the basin area to a complete recreational facility.

The third alternative provides for the hydraulic pumping of the spoil from the settling basin to the head of navigation, where it would be transferred to a waterborne vessel and transported to one of several proposed diked disposal areas in the Cleveland Outer Harbor. Final selection of the harbor disposal site will depend on minimization of adverse environmental impacts. The various possible diked disposal areas are shown in Figure C-6. The difficulties of pumping the material, and the cost and operation of the large vessels required, make this alternative undesirable.

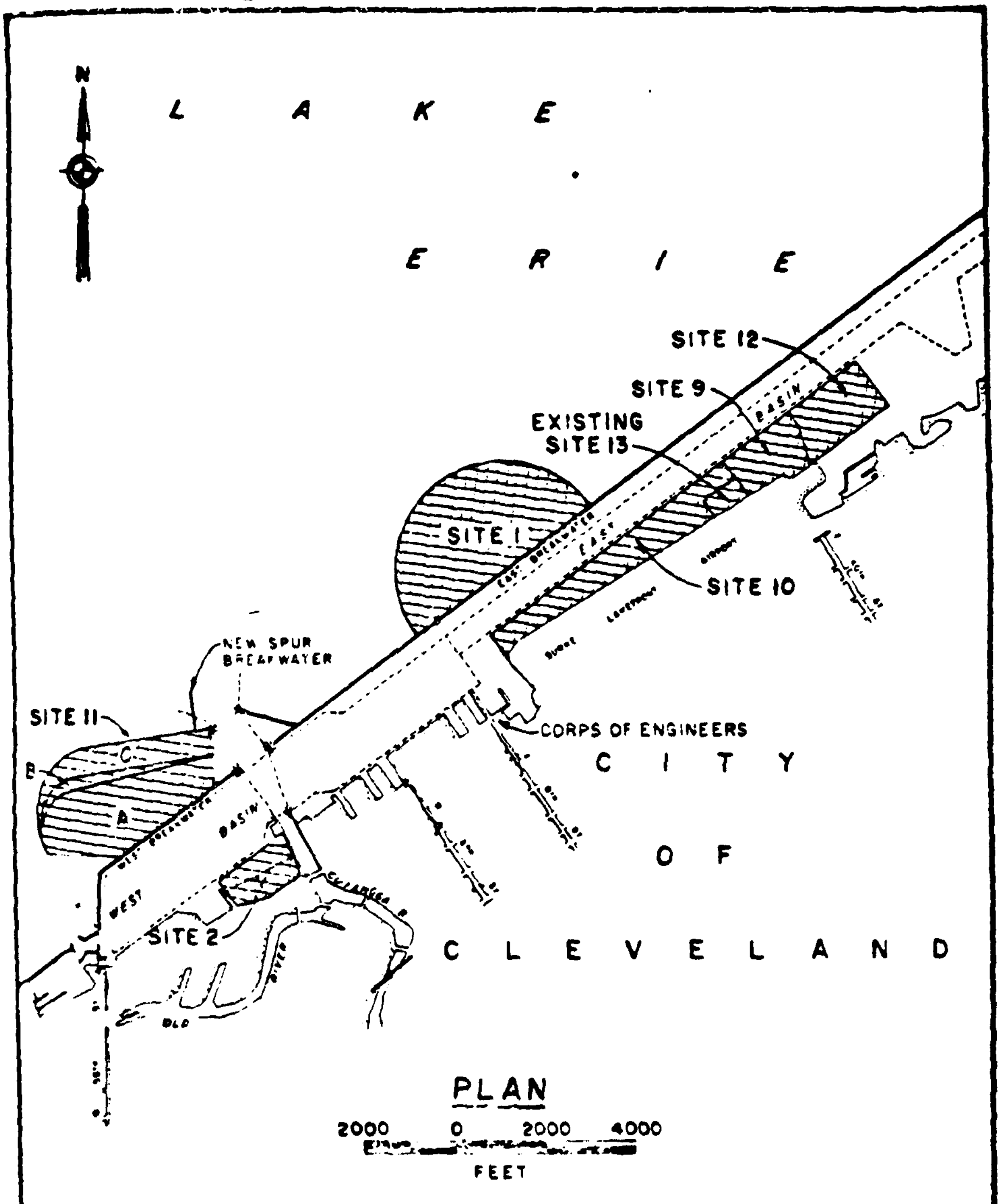
The cost of the current method of dredging sediment and disposing of it in diked disposal areas, based on bid proposals of August 1971, is $4.66 per cubic yard dredged and placed in the present diked disposal area. This compares with $1.89 per cubic yard dredged and placed in disposal sites under the Sauerman method and $1.75 per cubic yard with the hydraulic method.

The settling basin and nearby disposal sites at the proposed location present the potential for various experimental water quality enhancement measures. For example, injection of polyelectrolytes immediately upstream of such basins has been shown to increase the effectiveness of sediment removal. Incidental to this sediment removal, significant reduction in organic materials and bacteria has been demonstrated.

Another potential demonstration technique involves chemical coagulation and precipitation of phosphates, followed by dredging of the precipitate with the sediment. The recommended location of the settling basin immediately downstream of the Cleveland Southerly Wastewater Treatment Plant, where the maximum concentration of phosphates in the stream occurs, is ideal for such an investigation.

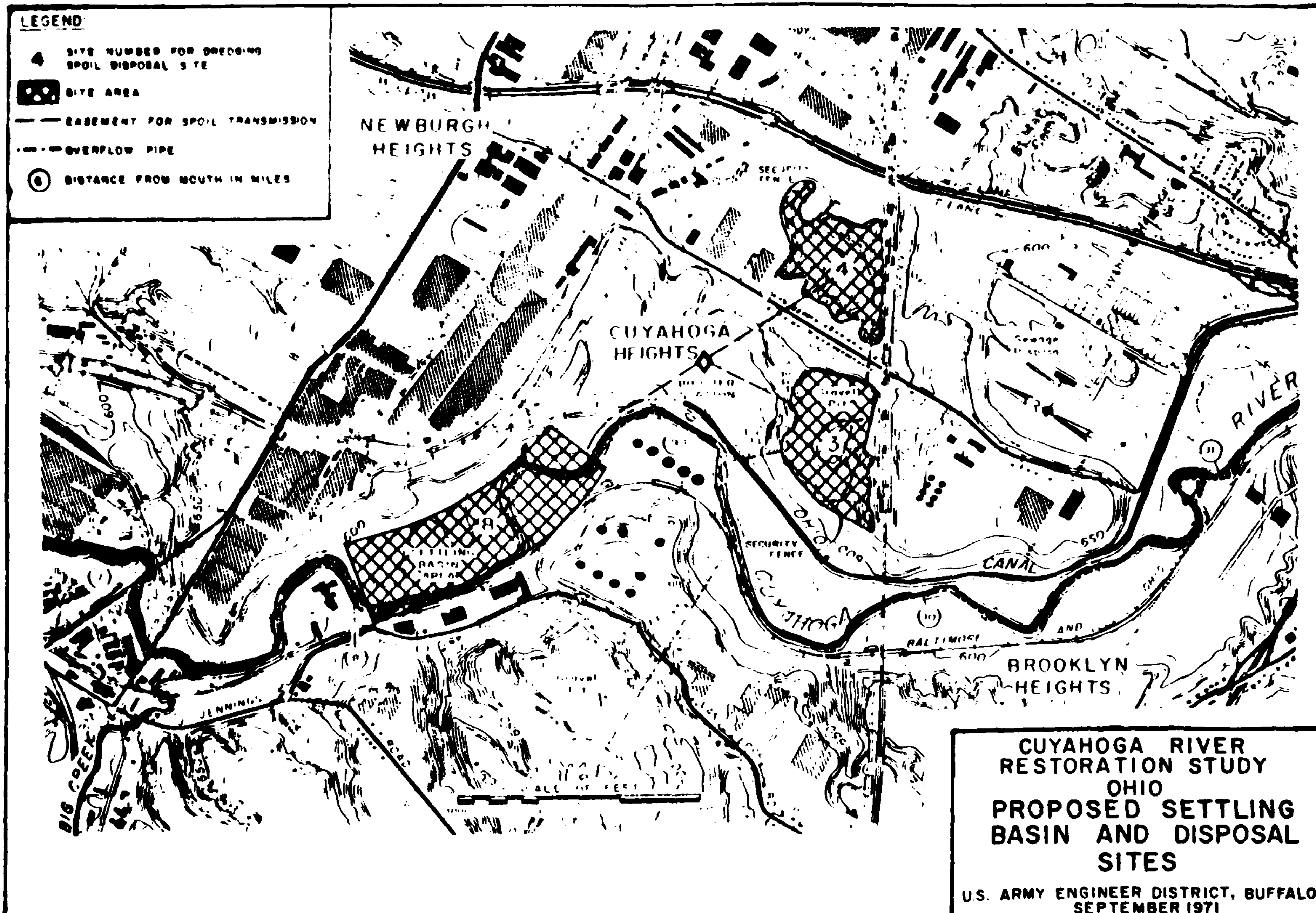
Finally, in-stream aeration of the river water leaving the basin, after successful removal of organic material, can be expected to improve the quality of the river water in the stretch between the settling basin and the head of navigation, improving the self-cleaning capability of the river, and ultimately reducing the contamination of Lake Erie.

Before any projects are undertaken, measurements and analyses must be made to determine baseline conditions. Additional measurements would be made during and after any project to evaluate its effects.



HARBOR DISPOSAL SITES

FIGURE C-6



CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN AND DISPOSAL SITES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
SEPTEMBER 1971

PLATE C-3

NCBED-PP 5 April 1979

Mr. Robert W. Teater, Director
Ohio Department of Natural Resources
Fountain Square
Columbus, OH 43224

Dear Mr. Teater:

In September 1971, the Buffalo District completed the First Interim Report for the Cuyahoga River Restoration Study. As part of this report, the Buffalo District Engineer recommended that four early-action programs be adopted. During its review of this report, the Board of Engineers for Rivers and Harbors (BERH) concluded, among other things, that a settling basin on the Cuyahoga River should also be considered as an early-action program. Accordingly, the Board conducted a public meeting on 19 January 1972, at Cleveland, Ohio, on the considered modifications. Based on the information presented at this meeting, the Board concluded that local interests were not prepared at that time to provide the required items of local cooperation for the settling basin and noted that substantial environmental issues would have to be resolved before implementing the plan. The Board, therefore, recommended that a settling basin on the Cuyahoga River be given further study and be considered for construction if the environmental issues could be resolved and the items of local cooperation met.

The Buffalo District is currently preparing, in conjunction with the U.S. Soil Conservation Service, a *Preliminary Feasibility Report* (PFR) on Erosion and Sedimentation in the Cuyahoga River Basin between Independence (river mile 13.8) and Portage Path (river mile 40.5) for the Cuyahoga River Restoration Study. The objectives of this PFR are to determine the prolific sources of sediment throughout the study area (from land and streambank erosion) and to identify methods of controlling erosion and sedimentation through structural and/or nonstructural means. We will provide you a copy of this report when it is completed.

EXHIBIT G-8

NCBED-PW
Dr. Robert W. Teater, Director

As an alternative to controlling erosion and sedimentation in the study area, the Buffalo District proposes to reexamine the settling basin concept outlined in the First Interim Report and considered by the Board for an early-action program. For your convenience, the pertinent information presented in the First Interim Report on the settling basin concept is provided in Inclosure 1.

At the 19 January 1972 public meeting, your agency expressed its reservations about the feasibility of the settling basin concept. A copy of your agency's statement, presented at this public meeting, is provided in Inclosure 2. It is requested that you review your agency's previous position on this matter in light of current conditions and provide me with your current views in order that we may incorporate them into our formulation and assessment of this alternative. A timely response to this request will be appreciated.

If you have questions on this matter, please contact me or Mr. Richard Aguglia, my project manager for the Cuyahoga River Restoration Study, at (716) 876-5454, extension 2263.

Sincerely yours,

2 Incl
as stated

DANIEL D. LUDWIG
Colonel, Corps of Engineers
District Engineer

STATEMENT BY WILLIAM B. NYE, DIRECTOR,
OHIO DEPARTMENT OF NATURAL RESOURCES

TO THE BOARD OF ENGINEERS FOR
RIVERS AND HARBORS

REGARDING THE FIRST INTERIM REPORT
AND CHANGES PROPOSED BY THE BOARD

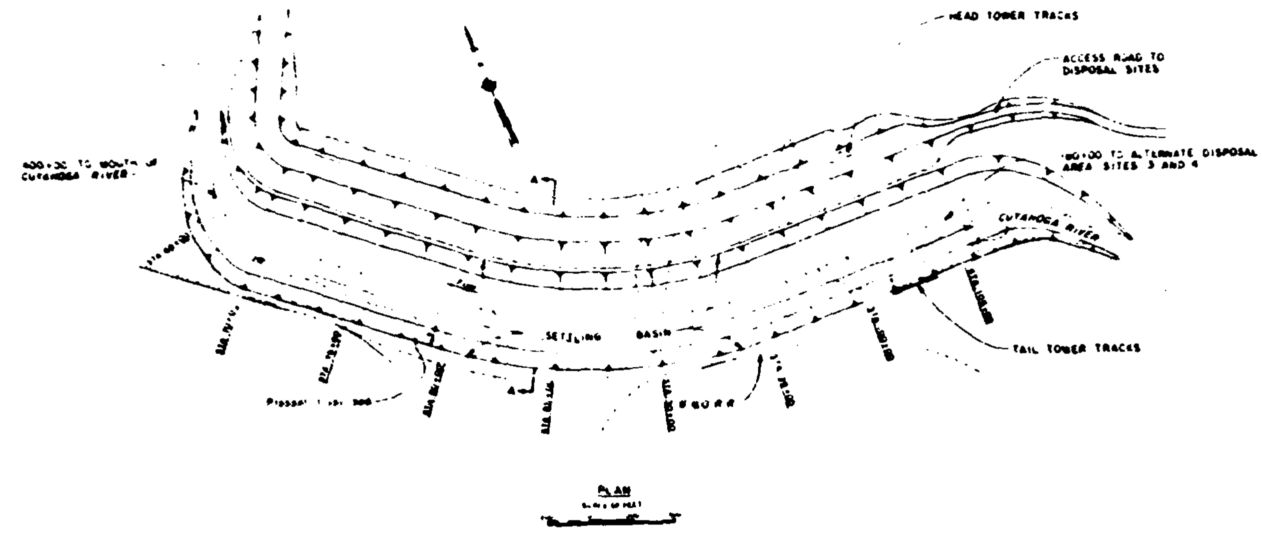
FOR THE

<u>CUYAHOGA RIVER, OHIO, RESTORATION STUDY</u>

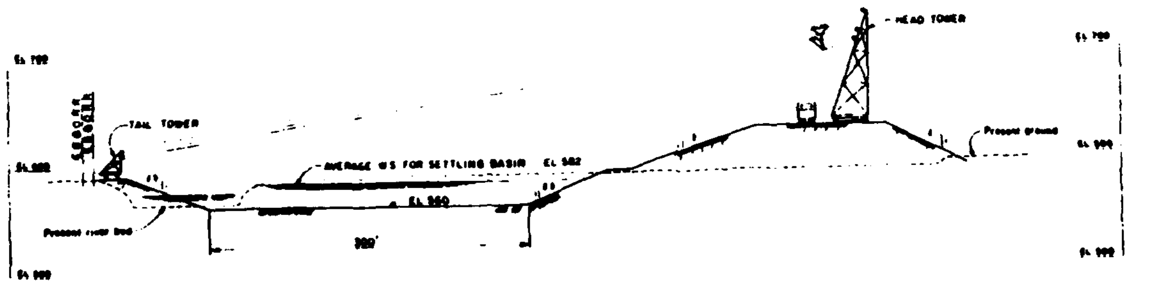
January 19, 1972

EXHIBIT C

Inclosure 2



PLAN



SECTION A-A

CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN
SAUERMAN DREDGING SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO

SCALE AS SHOWN

PLATE B-4

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

NA, S&PF, Morgantown, WV 26505

REPLY TO: 1540 Intradepartmental
3500 Cooperative Watersheds

January 25, 1979

SUBJECT: Cuyahoga River - Special Study

TO: Robert E. Quilliam
Room 522
200 North High St.
Columbus, Ohio 43215

As requested we have again reviewed forest land conditions in the Cuyahoga River Basin. Jim Patric, USDA, Forest Service, Northeastern Forest Experiment Station, participated in this review. A copy of the trip report is attached for your information.

We have also attached a copy of our July memo to George Stem listing our recommendations for future studies. However, we are aware of the unique conditions existing on the forest lands in the basin and do support additional studies to determine cause and effects of erosion from these lands. Jim Patric was asked to research this problem and help develop remedial measures. Jim was receptive to the proposal but subsequent ceiling reductions have curtailed his involvement at this time. The same limitations have been imposed on us and there appears little chance that the restrictions will be lifted within the immediate future.

The alternative to having the Forest Service conduct the research would be a cooperative study with a qualified university or college. It is probable that Forest Service Research would assist in such an effort. If such assistance is desired please contact Mr. Samuel F. Gingrich, Assistant Director for Research, 180 Canfield Street, Morgantown, West Virginia, 26505.

If we can be of any other help let me know.

Bernie Dubin

Floyd L. Wiles
Field Representative
Area Planning

cc: Sam Gingrich w/enclosure
Jim Patric w/enclosure
Karl A. Davidson w/enclosure
Harvey Kananen w/enclosure

EXHIBIT G-5

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

REPLY TO: 1500 External Relations November 22, 1978

SUBJECT: Visit to Cuyahoga River with Jim Patric

TO: Floyd L. Wiles
Field Representative
Area Planning

On November 6 and 7 Jim Patric and I visited the Cuyahoga River planning party. The purpose of the trip was to give Jim a look at the particular problems found on forest lands. We spent the afternoon looking at the forest land and meeting with Harvey Kananen, SCS, and National Park Service people. The morning of the 7th was spent with Harvey discussing possible actions on our part.

The significant points evolving from this trip are:

- It was recognized that there was a unique condition (lack of normal forest floor development) existing in the Watershed.

- Jim felt the problem was sufficient to warrant research emphasis.

- There is a possibility that the research effort could be funded by grant monies from the Corps.

- It was suggested (Harvey) that we submit letter to STC detailing our findings and suggest additional studies. If we want to explore the possibilities of grant study monies we should establish communication with the Corps Office in Buffalo.

When we returned to Morgantown it was learned that Jim Patric would not be able (because of ceiling cuts) to take a major role in this research effort. If any further work is done on this problem it looks like S&PF will have to do it.

BERNARD P. DICKERSON
Resource Planner

Incl 1

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NA-S&PF, Forestry Sciences Laboratory
180 Canfield Street, Morgantown, WV 26505

July 31, 1978

George L. Stem, Area Conservationist
Soil Conservation Service
Box 448
Highland Court Block
Medina, OH 44256

Dear George,

Bernie has reported to me the findings of the Interagency team reviewing erosion problems in the Cuyahoga River Special Study. He said the field trips and subsequent discussions were beneficial and enlightening. From his report, I have concluded that the forest land conditions encountered in the Cuyahoga Valley are somewhat unique and difficult to understand. Still I am reluctant to accept the high sheet erosion rates from forest land, based on the USLE, as valid without further study.

Therefore I recommend you proceed as discussed and:

1. Initiate a mainstem channel study on Furnace Run.
2. Conduct an in-depth stream bank erosion study on a tributary of Furnace Run; preferably Wheatley Run.
3. Simultaneously conduct a preliminary appraisal of sediment yields from the gullies within the Wheatley Run area.
4. Re-evaluate the impact of sheet erosion from forest lands relative to the above findings.

We in no way want to discount the seriousness of erosion from forest lands in the area. Rather, it is our desire to make sure we have unquestionably determined where the major problem exists so that our recommendations and alternatives are valid.

It is hoped that you will be able to undertake the additional studies outlined above. If we can assist in any way, please let me know.

Good luck.

Floyd L. Wiles

FLOYD L. WILES
Field Representative
Area Planning

incl 2

6200-11 (1/69)

NCBED-PW

5 April 1979

Jack Hively, Executive Director
Cleveland-Cuyahoga County Port Authority
101 Erieside Avenue
Cleveland, OH 44114

Dear Mr. Hively:

In September 1971, the Buffalo District completed the First Interim Report for the Cuyahoga River Restoration Study. As part of this report, the Buffalo District Engineer recommended that four early-action programs be adopted. During its review of this report, the Board of Engineers for Rivers and Harbors (BERH) concluded, among other things, that a settling basin on the Cuyahoga River should also be considered as an early-action program. Accordingly, the Board conducted a public meeting on 19 January 1972, at Cleveland, Ohio, on the considered modifications. Based on the information presented at this meeting, the Board concluded that local interests were not prepared at that time to provide the required items of local cooperation for the settling basin and noted that substantial environmental issues would have to be resolved before implementing the plan. The Board, therefore, recommended that a settling basin on the Cuyahoga River be given further study and be considered for construction if the environmental issues could be resolved and the items of local cooperation met.

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EXHIBIT G-6

NCBED-PW
Jack Hively, Executive Director

As an alternative to controlling erosion and sedimentation in the study area, the Buffalo District proposes to reexamine the settling basin concept outlined in the First Interim Report and considered by the Board for an early-action program. For your convenience, the pertinent information presented in the First Interim Report on the settling basin concept is provided in Inclosure 1.

At the 19 January 1972 public meeting, your agency expressed its reservations about the feasibility of the settling basin concept. A copy of your agency's statement, presented at this public meeting, is provided in Inclosure 2. It is requested that you review your agency's previous position on this matter in light of current conditions and provide me with your current views in order that we may incorporate them into our formulation and assessment of this alternative. A timely response to this request will be appreciated.

If you have questions on this matter, please contact me or Mr. Richard Aguglia, my project manager for the Cuyahoga River Restoration Study, at (716) 876-5454, extension 2263.

Sincerely yours,

2 Incl
As stated

DANIEL D. LUDWIG
Colonel, Corps of Engineers
District Engineer

Members of The Board, Colonel Hansen, honored guests, I am William B. Nye, Director, Ohio Department of Natural Resources.

It is a particular pleasure for me to be involved in this public discussion for three reasons: first, because the restoration and best use of the Cuyahoga River is very high on our list of resource priorities; second, because the realistic restoration of the Cuyahoga must be preceded by a series of public discussions-- like this one-- in which all interested parties participate; third, because I lived most of my life in Akron, a community along its shores. Some factors of restoration, such as adequate waste treatment and the meeting of stream water quality standards, will be enforced under Ohio law and need not be debated. Many other factors affecting the health of this River are less well defined and must be determined as we work together. The completion of the First Interim Report on the Cuyahoga River Restoration Study provides some important facts upon which we may base our joint discussions. As was pointed out in the Report, however, we must not dally too long in our deliberations. Those projects upon which we can readily agree and which clearly are needed should be pressed ahead soon. The patient is ill and needs our concern and our action.

Integration of Plans

Among the important next steps which can be taken is the integration of the provisions of this Report with the comprehensive Northeast Ohio Water Development Plan so that it may gain official state recognition. Members of my water planning staff will be pleased to meet with your planners of the Corps of Engineers in the near future.

Recreation Improvements in the Upper Cuyahoga

Planning integration, further refinement, and the public discussion are particularly important to guide actions along the Upper Cuyahoga upstream from Lake Rockwell. Long reaches of this stream provide important and fragile natural areas, easily destroyed by over-use or unwise manipulation. We urge that proposals for recreation development and for snagging and clearing in the stream reach upstream from Lake Rockwell be deferred pending completion of a recreation plan for the area. The plan should determine such factors as optimum carrying capacity for recreation and for natural area protection. It should make recommendations on shoreline ownership, natural areas, proposed scenic river designation, and possible action under the proposed Seiberling Bill creating a National Park or Recreation Area. The proposed recreation improvements provide a key means to controlled access for recreational use of the Upper Cuyahoga and their number, design, and location are critical. Where concern is raised, further study and correlation of completed studies is advisable.

Proposed recreational developments at Cuyahoga Falls and Kent, on the other hand, will apparently not affect endangered natural areas and are recommended for early action to support stream use activities already undertaken by these communities. Further consideration may be needed regarding adequacy of stream flow for canoeing in these areas.

Debris Removal

The proposals for removal of floating debris from the River and for its disposal in cooperation with existing municipalities are a recommendation of the Northeast Ohio Water plan and is urged for early action. We hope this program will also permit removal of debris from the shoreline of the River and from Lake Erie.

The Corps of Engineers, Buffalo District, has requested that the Department of Natural Resources serve as coordinator in providing assurances of local cooperation supporting implementation of the early action programs. In response to this request, we have corresponded with the concerned city officials of Cleveland, Cuyahoga Falls and Kent for such assurances. A favorable response from them is expected in the near future.

Flood Control Along Big Creek and at Cleveland Zoo

Frequent flooding at the Cleveland Zoological Gardens results in a serious degradation of the urban environment. At a time

when the impr ement of the quality of life in t inner city is a high national priority, we feel that the restoration of a key segment of this Cuyahoga River tributary must be pressed forward. Big Creek presently flows through underground conduits at the Cleveland Zoo. While we understand the reasons why the stream was diverted into concrete conduits and channels, it should be pointed out that such structures are degrading to the aquatic environment even during normal flows.

The replacement of the present inadequate conduits with a properly designed and landscaped open stream in harmony with the Zoological Gardens offers an important step toward the restoration of the Cuyahoga River and the improved quality of life in the urban area. The detailed choice among alternative stream locations, the specific landscaping designs, and the further consideration of 50-year versus 100-year flood design might best be worked out during project design operations. Our assessment of the environmental impact statement drafted by the Corps for this project has not yet been formulated due to need for detailed consideration of the foregoing alternatives by our engineering staff.

Settling Basin

The proposed settling basin would, if successful, meet an important objective of the Northeast Ohio Water Plan. We feel it is essential to control bed load sediments presently entering Cleveland Harbor. Pollution abatement projects recommended in

the Northeast Plan would go far to remove polluted solids but we recognize that urban storm runoff and combined storm sewer outflows will require some years to correct. Non-federal costs for this project are significant and we are not aware of funds immediately available for this purpose. Additional information is needed regarding proposed means for disposal of sediments and regarding possible detrimental effects on the Lake Erie shoreline due to interception of sediments. Based on satisfactory conclusion of the foregoing three matters, we would recommend that planning proceed.

We commend the staff of the Corps of Engineers for this Interim Report and look forward to further constructive discussion and resolution of problems in cooperation with federal and local interests. We thank the members of the Board of Engineers for their personal interest in this matter.

STATEMENT OF

RICHARD L. SCHULTZ, EXECUTIVE DIRECTOR

CLEVELAND-CUYAHOGA COUNTY PORT AUTHORITY

RE

PUBLIC HEARING, JANUARY 19, 1972

FEDERAL BUILDING, CLEVELAND, OHIO

CUYAHOGA RIVER RESTORATION STUDY

PROPOSED SETTLING BASIN

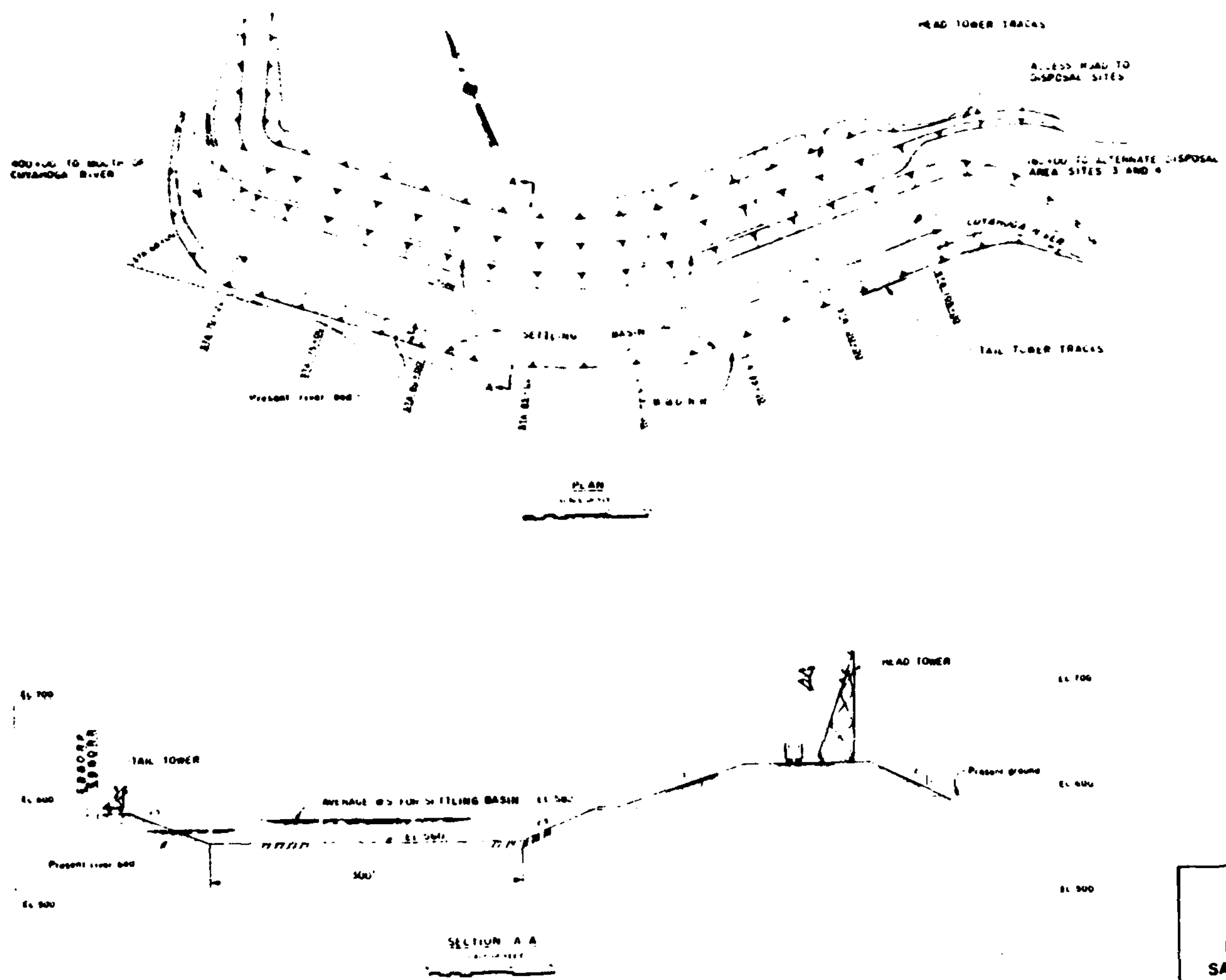
The Cleveland-Cuyahoga County Port Authority is an independent public body created and operating under the statutes of the State of Ohio. It was established in 1968 to promote the economic development of the Greater Cleveland area through the improvement of marine transportation facilities, and to this end it now operates some ten overseas cargo piers on the Cleveland lakefront. Its interest, however, is the waterfront countywide.

Accordingly, the Port Authority has a strong and continuing interest in both water quality improvement and dredging spoil disposal. In connection with the latter, the Authority has assumed certain responsibilities and looks forward to progress in the PL 91-611 spoil containment program. By letter to Colonel Hansen dated January 7, 1972, the Chairman of the Authority, Mr. Harry F. Burmester, set out the priorities of the Authority for action on the spoil area program, and I would like to offer a copy of that letter now to be made a part of the records of this meeting.

Briefly stated, the Authority position is that the River Settling Basin has considerable merit - particularly for water quality improvement in view of the contemplated precipitation of chemicals and aeration of the water - but as regards dredging spoil disposal only, we submit that other solutions deserve priority, even though the Settling Basin would remove a substantial portion of the river silt during its period of operation.

EXHIBIT D-1

Inclosure 2



CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN
SAUERMAN DREDGING SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO

SEPTEMBER 1971

PLATE C-4

CLEVELAND WORLD PORT

PORT OF CLEVELAND

CLEVELAND – CUYAHOGA COUNTY PORT AUTHORITY
101 ERIESIDE AVENUE CLEVELAND OHIO 44114 (216) 241-8004

January 7, 1972

Colonel Ray S. Hansen
Corps of Engineers
Department of the Army
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hansen:

This letter is written to outline the position of the Cleveland-Cuyahoga County Port Authority in regard to dredging, dredging spoil disposal, spoil disposal areas, and other related matters of concern to the Corps of Engineers.

The Authority's prime obligation is the economic development of the Cleveland area through efficient marine transportation facilities. We, therefore, have a continuing interest in the improvement and maintenance of Cleveland Harbor channels, and a deep concern that this work be done as expeditiously and economically as possible, consistent with current ecological constraints.

This philosophy recognizes the desirability of spoil containment areas for the forseeable future, and to that end, the Authority accepted the responsibility of designation as local coordinator for the PL 91-611 spoil area program despite the Authority's limited resources.

We believe the maximum overall benefits from the spoil area program will be realized through well-planned diked area landfills on the lakefront. Specifically, we believe such a landfill north of the existing harbor would create substantial values through additional commercial and recreational areas - and that this project would be consistent with the long-range development of the Harbor and the proposed Jetport.

EXHIBIT D-2

Therefore, we would like to make the following points:

(1) To the extent that justification for the Settling Basin implies that silt disposal inland is preferable to lake disposal, contained or otherwise, we disagree. We believe everyone recognizes that it is the pollutants, not the sediments, that are causing the premature aging of Lake Erie. If, as a collateral benefit of the Settling Basin, there were to be silt disposal inland, that would be quite welcome. If a principle were to be established that silt and dredging spoils should be disposed inland, the economic consequences would be staggering - and it would fly in the face of nature. The deposition of river silt in receiving bays, gulfs, lakes, etc., has been going on for some time now, and we believe containment areas in the receiving waters are a suitable solution that offers the minimum conflict with nature. In the meantime, we hope that proper conservation practices reduce silt loads.

(2) The water treatment features of the proposed Settling Basin are quite sophisticated. Unquestionably these are all desirable, but it should be recognized that these are in lieu of adequate treatment of industrial and municipal wastes upstream. As in the case of the dredging spoil disposal areas, the sins of the upstream river users are visited on the community at the head of navigation - and the Cleveland area may have to carry a disproportionate share of the costs of poor conservation and poor water quality control, with no way to pro-rate these costs back to the offenders. Therefore, we believe it is important to treat the Settling Basin as a unique project, federally funded as in the case of debris removal - and not as a local obligation in whole or in part, as is the case with spoil disposal areas. Along this line, we do not believe the Settling Basin should establish the precedent that water treatment is to be included as part of the PL 91-611 spoil area program - at least not without some restructuring of that program and reallocation of costs.

Thank you for this opportunity to comment. The efforts of the Corps are indeed appreciated, and as indicated earlier, we believe the Settling Basin project does have much merit.

RLS:mes

CLEVELAND WORLD PORT

PORT OF CLEVELAND

CLEVELAND – CUYAHOGA COUNTY PORT AUTHORITY
101 ERIESIDE AVENUE CLEVELAND OHIO 44114 (216) 241-8004

December 10, 1971

Colonel Ray S. Hansen
Corps of Engineers
Department of the Army
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Hansen:

The Cleveland-Cuyahoga County Port Authority has had an opportunity to review the First Interim Report of the Cuyahoga River Restoration Study and we commend the Report in general, and the recommended Early Action Program in particular. In regard to the latter, we are especially interested in the Debris Removal Program. Your report indicates an initial cleanup cost of $1,122,000.00 for this, with an average annual cost thereafter of $35,000.00.

The debris removal problem in Cleveland Harbor has been a continuing one, and as you know, public hearings were held in Cleveland in January, 1965 to develop the magnitude of the problem. As we understand it, that hearing resulted in a request that the Corps add that function to its other harbor maintenance work at Cleveland (as is done in a limited number of ports including New York) but this request stalled in the Bureau of the Budget when that agency tried to determine the implications of possibly setting a precedent for such work at other ports.

In view of the fact that debris removal is a Corps function in some major ports, we have never shared the Budget Bureau's concern about setting precedent. Further, as in the case of polluted dredging spoils, we feel strongly that debris removal is a problem created along the entire reach of a river, and that it is inequitable to require a local agency located at head of navigation to solve the entire problem because of its limited tax and/or revenue base.

EXHIBIT D-3

Colonel Ray S. Hansen
Corps of Engineers
December 10, 1971
Page 2

Accordingly, we strongly endorse your Report's recommended early action debris removal program, and by copy of this letter, are urging the Cleveland area Congressional Delegation to support funding in the fiscal 1973 budget.

As you know, the City of Cleveland undertook a local debris removal program in the years 1967 to 1970, but this program was discontinued due to the City's desperate financial condition. The Port Authority has not undertaken this obligation because its available funds are committed to port facility expansion and its tax revenues are limited to a five-year life operating levy. In view of the need to periodically revote such a levy, we feel it is impractical for the Authority to start such a project when it may have to discontinue it shortly.

The Authority is vitally interested in debris removal and since its jurisdiction is county-wide, we feel it is the appropriate coordinating agency. This obligation we are prepared to undertake, to the extent of our manpower and financial limitations. For the reasons set out above, we believe the Corps is the appropriate agency for the action program, and we hope all concerned will assist in getting your recommended program started promptly.

Sincerely,

Harry F. Burmester
Chairman

HFB:mes

CC: Mr. Barry F. Pritchard
Corps of Engineers (Cleveland)

Colonel A. D. Wilder, Resident Member
Board of Engineers for Rivers and Harbors

Colonel Ra_ S. Hansen
U.S. Army Corps of Engineers
January 7, 1972
Page 3

However:

(1) The presently proposed basin site involves approximately $1 million of land acquisition - 100% for the account of the coordinator (Authority). At present, the Authority has obligated all its available funds for terminal area expansion, the settling basin has no revenues that could be hypothecated for a borrowing, and the only method of financing the site acquisition would be a local tax levy - and a favorable vote could require a considerable amount of time.

(2) In view of the questionable desirability of inland landfill with spoils, 100% cooperation from the affected landowners and communities cannot reasonably be anticipated. Since the land acquisition is a local obligation it will require action by the Authority rather than the Corps - and this could pose delay because the Authority's ability to negotiate and appropriate is limited.

(3) The spoil areas that can be economically reached from the presently proposed settling basin would apparently fill in 10 years -- negating #3 above.

We are keenly aware that cost of maintenance dredging will be an important factor in continued maintenance of our Harbor. In fact, this is a compelling argument for the proposed settling basin, based on the economics developed to date. Since it is the long run costs that could eventually make it uneconomical to maintain our port, we believe the investigations we have recommended would be time well invested.

In brief, we feel some delay before proceeding with the upstream settling basin program is appropriate. Our concern, however, is not intended to delay the other early action programs recommended by the Cuyahoga River Restoration Study, specifically the river and harbor debris removal program. By my letter dated December 10, 1971, the Authority went on record endorsing the debris removal, and we reaffirm that position again.

Your interest is very much appreciated, and we look forward to progress on our spoils disposal program.

Sincerely,

Harry F. Burmester
Chairman

HFB:mes
CC: Mr. Barry Pritchard
Corps of Engineers

We recognize certain engineering constraints in reaching this ideal solution immediately, and we accept the necessity for using other lakefront sites in the interim. We cannot agree at this time that spoil disposal inland is a necessity - or in fact that it would be preferable. In view of the nature of the dredged materials, placing spoils beneath good lake landfill instead of on top of good countryside appears to be desirable both economically and ecologically.

We further recognize the urgent need for immediate progress on these spoil areas in view of the possibility that an absolute prohibition on uncontained spoil disposal could result in curtailment of Cleveland Harbor's maintenance dredging.

Therefore, in its capacity as local coordinator for Cleveland Harbor, the Authority submits the following as the priorities for action:

(1) Construction of spoil area #12, east of Burke Airport and within the Harbor as an interim 2 - 3 year solution.

(2) Investigation of adaption of the existing settling basin at head of river navigation to incorporate the benefits projected for the new settling basin proposed above navigation.

(3) Investigation of construction of spoil area #1 north of the harbor breakwater for a permanent solution.

As noted above, our order of priorities does not emphasize the upstream settling basin proposed in the Corps' 1968 Study of Cleveland Harbor alternates, and now proposed as an early action program under the Cuyahoga River Restoration Study. We believe the Basin concept has considerable merit, as demonstrated by the existing one, but the following factors must be weighed:

(1) The settling basin proposed would be the lowest cost method of handling about 50% of the Harbor's annual dredging requirements under PL 91-611 program.

(2) Its favorable economics can be used to average down the cost of <u>any</u> of the alternate spoil disposal areas inside or outside the Harbor.

(3) The settling basin concept <u>could</u> provide a permanent low-cost method to handle a substantial part of Cleveland's dredging requirements for the future - after expiration of PL 91-611, and as long as the lower Cuyahoga is navigated.

THREE RIVERS WATERSHED DISTRICT
1917 SUPERIOR BUILDING
CLEVELAND, OHIO 44114

Telephone 621-1126

Statement to Board of Engineers for Rivers and Harbors, Corps of Engineers, Department of the Army, in re Cuyahoga River Restoration Study
First Interim Report
January 19, 1972 - Cleveland, Ohio

My name is George H. Watkins. I am Secretary-Treasurer of the Three Rivers Watershed District which is the regional water resource planning agency for the drainage basins of the Chagrin, Cuyahoga and Rocky rivers. This statement is made on behalf of the District Directors.

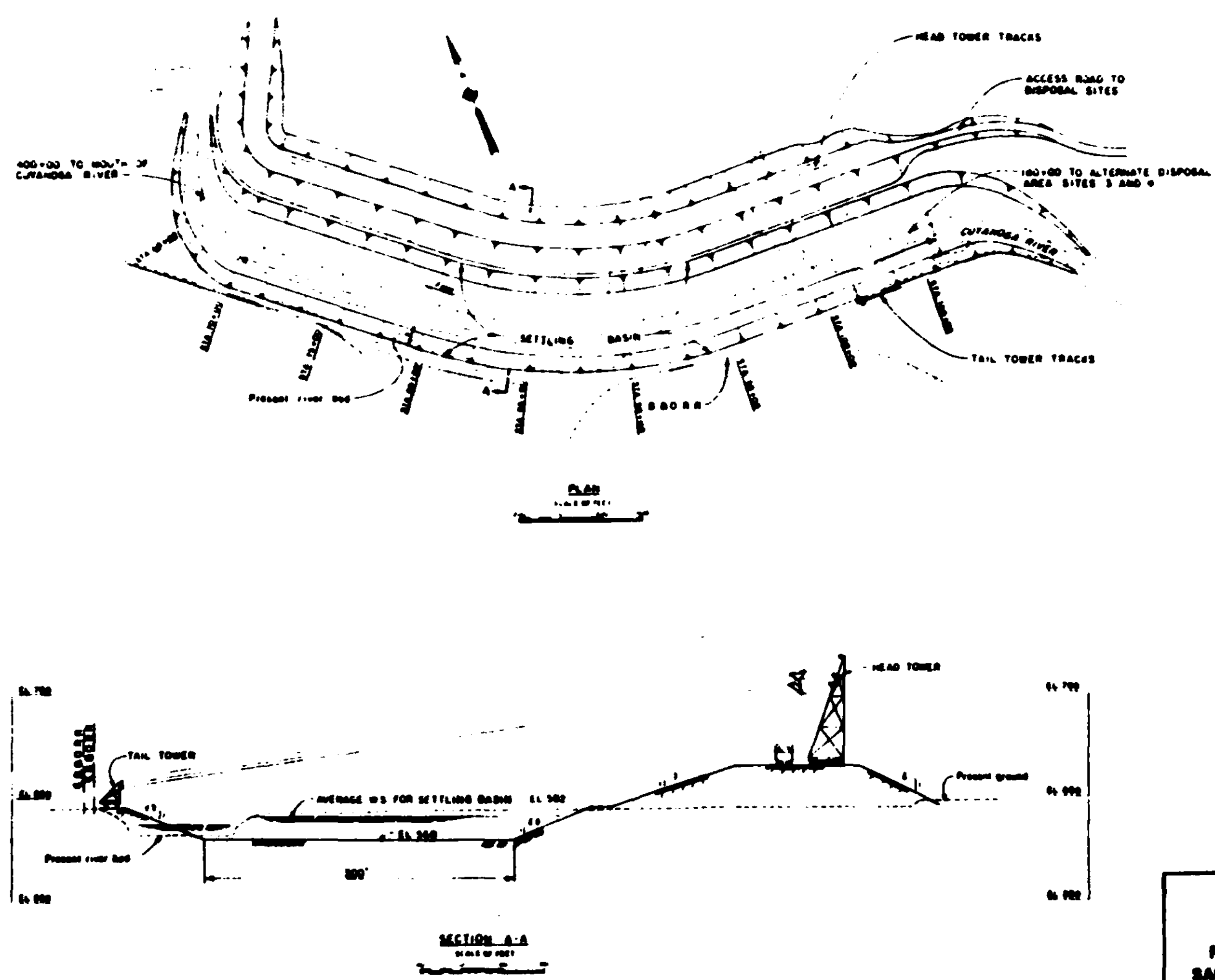
Since its beginnings in 1965, the District has worked with the U. S. Army Corps of Engineers to the best of its ability. The District has been frank in its work with the Corps. It has carried through much of the local liaison work so necessary in bringing Corps projects to fruition. It has attempted to guide the Corps to apply its much acclaimed planning capabilities to the critical problems of the District. It has kept the proposed flood control channel of the Cuyahoga River free of obstruction which would preclude construction of this needed improvement. Largely through its efforts the Cuyahoga Restoration Study was converted from a narrow examination of one reach of the Cuyahoga River to a broader examination of the whole basin.

The Cuyahoga River Restoration legislation that finally was passed by Congress included a wide spectrum of water resource management - water quality, environmental quality, recreation, fish and wildlife, and flood control. It drew particular attention to clearing, snagging and removal of debris from the river's bed and banks; dredging and structural works to improve streamflow and water quality; and bank stabilization by vegetation and other means.

The Corps, in responding to Congress, has chosen to include in the Restoration Study all of the projects it has had underway in the basin. There is some clear advantage in this. There is also a clear disadvantage since it may produce the impression that

EXHIBIT E

Enclosure 2



CUYAHOGA RIVER
RESTORATION STUDY
OHIO

PROPOSED SETTLING BASIN
SAUERMAN DREDGING SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO

SCALE AS SHOWN — SEPTEMBER 1971

PLATE D-4

the Corps studies on various projects are at equivalent stages of the planning process. In reality they are not. With that background, let us look at the subject of this hearing.

There were four project areas recommended in the Restoration Study by the Buffalo District Engineer and concurred in by the North Central Division Engineer in Chicago for early-action by the Corps.

These included:

1. Six canoe stations and related facilities in the upper Cuyahoga River.
2. Snagging of some debris from the river at Mantua.
3. Cleveland Harbor and navigation channel debris and drift removal.
4. Provisions for flood abatement on lower reaches of Big Creek.

These four proposals were specifically mentioned by the Corps at its public meeting in Akron in August, along with flood control on the lower Cuyahoga and vigorous application of the provisions of the 1899 Navigation Act.

The canoe ramps and river snagging at Mantua are simple jobs requiring little in the way of sophisticated data gathering or engineering planning. The principle issue is whether the people along the reaches involved want Corps intervention and financial help.

The debris and drift removal from the Cleveland navigation channel and harbor is also a relatively uncomplicated process. It was the subject of a Corps study in 1966 which resulted in recommendations to proceed both from the District Engineer and the Division Engineer. Since the Corps has responsibilities regarding navigational hazards, and since five years have passed since the study produced positive recommendations to proceed, it appears quite appropriate to do so.

The Big Creek proposal has been under development since 1969. Alternates to earlier proposals examined by the Corps and found unsatisfactory were developed by local

interests led by persons associated with the Cleveland Zoo. By the middle of 1971 definite plans had been worked out to provide necessary protection to the Zoo and adjacent flooded reaches. Cooperation of involved property owners has been obtained. We understand the local share of funding has been assured. The Corps District Engineer and Division Engineer have recommended proceeding on the project as part of the early action phase of basin restoration work. The Board of Engineers now propose to defer this project. We can seen no valid reason for delay in implementation of this project for needed flood control on Big Creek on which the Corps and local interests have worked so well together and so hard to bring to fruition. We are really doubly surprised at the proposed deferral, since this project will produce an attractive stream where now no stream exists and it is in a reach with an extraordinarily high public exposure because of the Zoo. It is hard to imagine a project with more favorable attributes to enhance public attitudes toward the Corps.

The Board of Engineers have proposed to add two projects for early action, replacing the Big Creek project; one is a settling basin upstream of the navigation channel which is at present a settling basin, and the other is a pilot sediment removal program.

The settling basin was inserted in 1969 into a study the Corps has had underway since 1960 on Flood Control in the lower Cuyahoga River. The basin has nothing to do with flood control per se, although it would in fact flood-proof that reach of the river. Its virtue as stated in the 1969 Corps report lay in "its utility as a means of abating pollution in Lake Erie." This was expanded in the same report as being "for pollution abatement, Lake Erie restoration, and navigation."

Removal of sediment from the navigation channel is now and will continue to be required until settleable sediment discharge to the river can be controlled. Disposition of that sediment which currently contains oil and undecomposed organic material is the problem. Putting it into the open lake does not create measurable adverse water quality effects but anyone who has seen the black ooze dredged from the river instinctively feels it objectionable and willingly accepts the idea that it is bad and should

be disposed of elsewhere, at least until such time as pollution control improvements make it "clean." Disposal in diked areas along the harbor has been tested. EPA has said contaminants are contained in this procedure. Thus the present procedure is satisfactory. Why then the sediment basin?

The apparent reason is economics. Figures are presented which show it is cheaper to take sediment out the river from the proposed basin and pump it to two landfills in Cuyahoga Heights than to dredge it from the river and dispose of it in diked areas along the harbor.

Added reasons for the basin appear to include its planned use for experiments to remove organic material, bacteria and phosphates as well as to examine reaeration techniques. These are bonuses that are anticipated. Ultimate use of the basin for recreation is also anticipated by the Corps.

The cost estimate is $4.1 million of which the Federal Government would pay $2.7 and some unspecified other group would pay $1.4 million.

We feel the Board of Engineers has not justified the need for this project and that it basically is in conflict with their avowed purpose of restoring the Cuyahoga River to "natural or near natural conditions." The project deals with an effect rather than a cause of river degradation.

A number of projects proposed in the Restoration Study to get at causes of sedimentation and reduce sediment production have been ignored for early action. Construction of the sediment basin would tend, we feel, to lessen the pressure to reduce sediment load and push these vital projects further into the future.

It may be appropriate to mention a few of these sediment reducing proposals in the Restoration Study summary:

1. pg. 40 Water Quality: Provide erosion control and repair severely eroded areas.
2. pg. 41 Water Quality: Examine effects of sediment removal on ground water quality.

3. pg. 50 Fish and Wil''ife: Remove or cover polluted se''ments...

4. pg. 51 Aesthetics: Begin reforestation to reduce sediment inputs.

5. pg. 63 Erosion and Sedimentation: Prevent washwater solids from sand and gravel pits from entering the river.

6. pg. 64 Erosion and Sedimentation: Stabilize the stream in parts of the lower Cuyahoga.

7. pg. 64 Erosion and Sedimentation: Conduct a detailed basin-wide sediment survey to determine current sources and rates of sediment yields.

8. pg. 72 Navigation: Control erosion in upland areas.

9. pg. 72 Navigation: Control sediment from urban areas.

This list shows Corps recognition of the rather broad beneficial implications of sediment reduction. It also by inference indicates our general level of ignorance about its sources, its control and its effects in the river and upon the river environment.

While we recognize the desire of the Corps to do something visible by way of river restoration, we believe that spending over $4 million on a device to remove sediment is attacking the problem at the wrong end. It is at least questionable whether land disposal in a congested area of what the Corps says are polluted sediments is wise let alone acceptable to the residents; we question expenditures of this magnitude on data collected in 1952, and we have found no local agency willing to put $1.4 million into this project. We feel this project should be postponed until its need is clear.

By appropriate publicity the Corps can make visible an effort to find and control sources of sediment before it gets to the river. We support the early planning proposal in the Restoration Study involving a detailed basin-wide survey. Such an investigation is basic to sound progress and supportable programs. We agree with the Corps appraisal that it is "an important early need."

If the Corps has the necessary power under the 1899 Act to control sediment discharge from gravel washers cited in their study, we feel application of that power would be a

constructive early action project to control one known source.

The Board of Engineers have also proposed a pilot sediment removal program. They are uncertain as are we of the results that might be generated by such a pilot program. We can easily visualize some rather dire results and feel quite certain many people in the District will have a negative gut reaction to anything referred to as river dredging. As we understand the proposal, however, certain investigations would be completed and evaluated prior to any sediment removal. As stated in Appendix C of the Restoration Study these would include:

1. A complete sediment survey of the basin which would include source identification, production rates, soil loss estimates, reservoir sedimentation rates - really a sediment material balance for the basin - as well as determination of present and proposed land use and ownership.
2. Identification of chemical, physical and biological characteristics of bottom materials, including mapping of the stream bottom.
3. Establishment of baseline conditions in reaches that are selected for sediment removal.
4. Evaluation of impacts of disturbing the sediments both short and long range.
5. Evaluation of not disturbing or removing the sediments.
6. Determination of extreme quality conditions of the river related to seasonal... flows, input of pollutants, assimilative capacity of the river, and action of bottom deposits on water quality.

We feel that if such preliminary work is done, the result of sediment removal can be assessed with sufficient accuracy as to make predictions valid. We assume pilot dredging would take place only where the predictions showed net positive gains.

It seems to us this proposal has considerable merit for the Cuyahoga and that the information gained will be of value not only in this basin but elsewhere. Source and rate identification will provide guides to localized sediment control.

The District will support these investigations, reserving judgement on dredging until specific projects have cleared the proposed evaluation procedures.

We must record our disappointment that the early action proposals do not include the lower Cuyahoga flood control project, which the Corps has apparently now included in the river restoration work. This project has been under study by the Corps for over eleven years. There are 11 pages of documentation in the Restoration Appendix D showing why this flood control project from Tinker's Creek to the Head of Navigation should go forward. If the Board of Engineers wants action, they should be able to move this project. Without it an Intermediate Regional Flood would put the Southerly Waste Water treatment plant out of commission not to mention the business establishments all through the lower Valley.

This is a channel widening project and many people react adversely to anything that smacks of "channelization." The Corps as a result has become pretty gun-shy and is now promoting *flood plain management and floodway zoning* as a sounder flood protection alternative. We certainly agree, but as yet we have not quite figured out how flood plain zoning at this point in time is going to protect Cleveland's Southerly waste water treatment plant or other investments already made in the Valley.

The Corps obtained in October 1969 in writing all the local assurances of cooperation they asked for in the study report, but in the same month returned with additional demands which the local units of government could not legally give. It is now 1972 and we feel that the Corps should move this project to a position of high priority, promptly finish its reevaluation as suggested in the Restoration Study, and get moving to protect this critical area.

We appreciate this opportunity to have presented our views to the Board of Engineers and pledge our continued collaboration with their officers and employees in furthering the improvement of water resources and their management in the Three Rivers Watershed District.

CLEVELAND WORLD PORT

PORT OF CLEVELAND

Cleveland-Cuyahoga County Port Authority

101 ERIESIDE AVENUE
CLEVELAND, OHIO 44114
(216) 241-8004

April 18, 1979

Colonel Daniel D. Ludwig
District Engineer
Department of the Army
Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Ludwig:

We wish to acknowledge receipt of your April 5, 1979 letter relating to Settling Basins on the Cuyahoga River and consideration of an Early Action Program.

We have referred your letter to the Chairman of our Land Development Study Committee, Loran F. Hammett, for review and adoption of a position by the Cleveland-Cuyahoga County Port Authority at our May 11, 1979 Board Meeting.

Upon a position being adopted, I will relay the information to you so that it might be incorporated in your Preliminary Feasibility Report.

Sincerely,

J. R. Hively
Executive Director

JRH:ms

cc: Loran F. Hammett
Cleveland Port Authority

EXHIBIT G-9

PORT OF CLEVELAND

Cleveland-Cuyahoga County Port Authority

CLEVELAND WORLD PORT

101 ERIESIDE AVENUE
CLEVELAND, OHIO 44114
(216) 241-8004

May 15, 1979

Colonel Daniel D. Ludwig
District Engineer
Department of the Army
Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Ludwig:

SUBJECT: Preliminary Feasibility Report on Erosion and Sedimentation in the Cuyahoga River Basin

As we advised you in our April 18, 1979 letter, we referred your April 5, 1979 letter to the Cleveland-Cuyahoga County Port Authority's Land Development Study Committee for review and a current policy position.

After discussing the enclosures to your letter of April 5, 1979, our Land Development Study Committee has determined that our position should be basically the same as adopted by our letter dated January 7, 1972.

As you know, we are vitally interested in the continuing growth of the Port of Cleveland through commercial navigation, deepening of the channel to accommodate 1,000 foot ore vessels and the creation of appropriate land fill in designated areas through the use of spoils containment dikes. We feel the present procedure of constructing dikes on the lakefront best suits the growth of the Port of Cleveland and meets the environmental requirements of the area. However, this does not mean that we will not participate and cooperate in the final decision or study by the Corps of Engineers.

Sincerely,

J. R. Hively
Executive Direct

JRH:ms

EXHIBIT G-10

THREE RIVERS WATERSHED DISTRICT
1204 SUPERIOR BUILDING
CLEVELAND, OHIO 44114

Telephone: 621-1126

April 13, 1979

Colonel Daniel D. Ludwig, District Engineer
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Ludwig:

Your letter of 5 April 1979 concerning further study of a settling basin near mile point 8 on the Cuyahoga River has been reviewed.

Since the January 1972 meeting with the Board of Engineers some conditions bearing on further study have changed. Among them are:

1. Construction of additional contained dredgings disposal capacity.
2. Increased doubts about the wisdom of contained disposal of dredgings as compared to open lake disposal.
3. Iron ore delivery systems and their implications for lakefront unloading and shallower draft river traffic.
4. An investment committed and underway of $200 million or so in facilities at Southerly wastewater treatment plant to produce a low phosphorus, nitrified, filtered effluent.
5. Increased resistance by the public to unnecessary government and governmental waste and the taxes to pay for each.

We have also reviewed our January 1972 testimony which you kindly appended to your letter. Nothing has happened to date to suggest changes in it. Your study with the SCS of erosion sources and controls in the Central Basin of the Cuyahoga will, in this connection, be examined carefully and, in fact, we look forward to its publication.

Very truly yours,

George H. Watkins

George H. Watkins
Secretary-Treasurer

GHW:kep
cc: R. L. Lucas - Ohio Dept. of Natural Resources

EXHIBIT G-11

ODNR
Ohio Department of Natural Resources
Fountain Square · Columbus Ohio 43224 · (614) 466-3770

May 2, 1979

Colonel Daniel D. Ludwig
District Engineer
U.S. Army Engineer District - Buffalo
1776 Niagara Street
Buffalo, New York 14207

Dear Colonel Ludwig:

My staff and I recognize that potential benefits could result from the proposed settling basin project in the Cuyahoga River Basin.

Of the alternatives suggested, we consider alternatives one and three least desirable. Alternative two and the chemical coagulation and aeration demonstration projects elicited more favorable review comments. I mention this assessment realizing that you may wish to save time and effort if the cost estimates for the alternatives are updated.

We are looking forward to receiving a copy of the Preliminary Feasibility Report on Erosion and Sedimentation in the Cuyahoga River Basin. At that time, we can determine which sites are still available and what agencies could benefit from the project.

Meanwhile, if we can be of assistance by providing input for the joint U.S. Soil Conservation Service-U.S. Army Corps of Engineers study, please feel free to let us know how we can help.

Sincerely,

Robert W. Teater

ROBERT W. TEATER
Director

RWT:dkc

EXHIBIT G-12

APPENDIX H

STUDY MANAGEMENT

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

CUYAHOGA RIVER, OHIO
RESTORATION STUDY
THIRD INTERIM PRELIMINARY
FEASIBILITY REPORT
ON
EROSION AND SEDIMENTATION

APPENDIX H
STUDY MANAGEMENT

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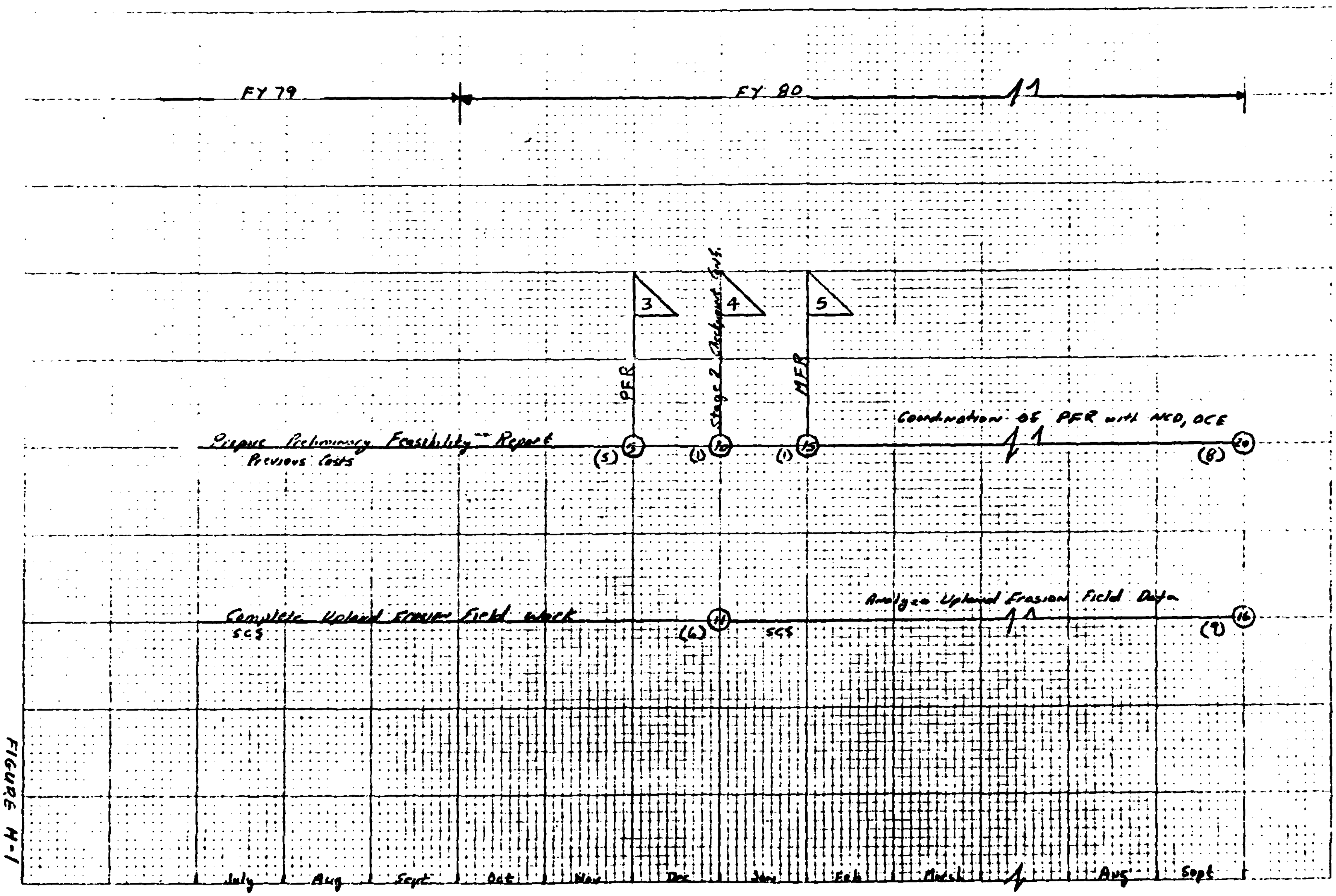
FY 79
FY 80
PER
Stage 2 Checkpoint Conf.
MER
3
4
5
Prepare Preliminary Feasibility Report
Previous Costs
(5)
5
(1)
10
(1)
15
Coordination of PER with NCD, OCE
(8)
20
Complete Upland Erosion Field Work
SCS
(6)
11
SCS
Analyze Upland Erosion Field Data
(9)
16
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
Aug
Sept

FIGURE H-1

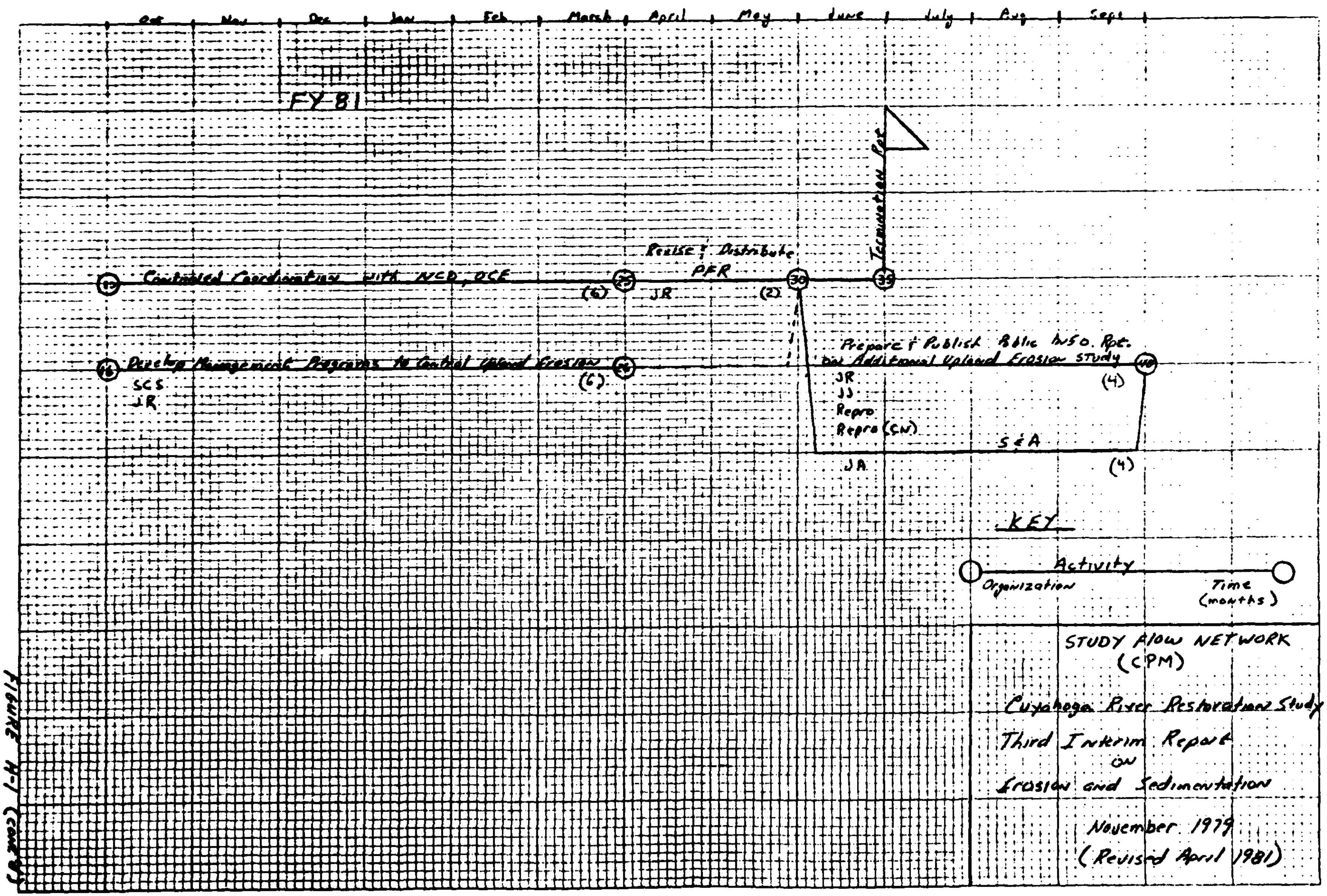

FIGURE A-1 (cont'd)